ELECTROMECHANICAL
components & systems
DESIGN
6
MAY 1958

CREATIVITY and PRODUCIBILITY

Basic research has been described as "a search for knowledge, unfettered by production demands." At Avco, we realize that fundamental new ideas cannot be programmed in advance to fit the needs of even the highest priority schedule. There will always be room here for this kind of basic creative work.

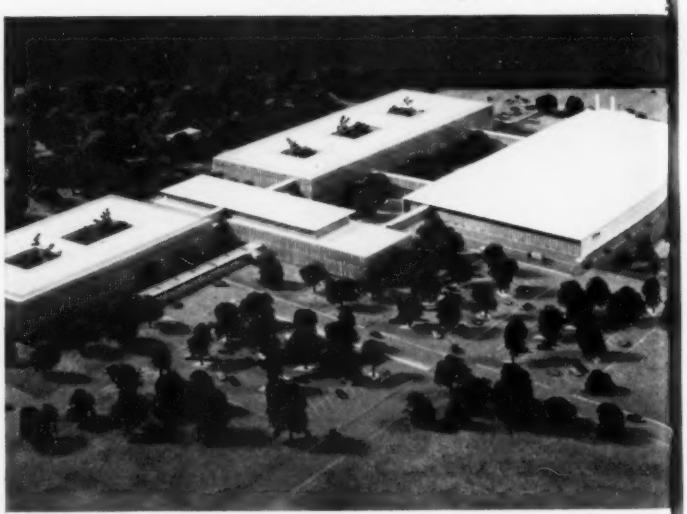
Yet, as an industrial research operation, we want to realize the material benefits that have historically resulted from scientific breakthroughs. Economic common sense and national security require an industrial research structure that can transform the idea in a scientist's brain into workable, useful hardware.

We see nothing inconsistent in the pursuit of new products simultaneously with the pursuit of new ideas—and doing both under the same roof. Rather, we feel that the continuous feedback resulting from close association of basic research people, applied scientists and engineers, test engineers and product engineers does as much for creativity as for producibility. And America's future depends upon a good supply of both.

Robert D. Grange

Robert D. Grange,
Manager, Prototype Development Department

Robert D. Grange



Pictured above is our new Research and Development Center now under construction in Wilmington, Massachusetts. Scheduled for completion this year, the ultramodern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division.

Avco's new research division now offers unusual and exciting career opportunities for exceptionally qualified and forward-looking scientists and engineers.

Write to Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Division, 20 South Union Street, Lawrence, Massachusetts.

Avco
Research & Advanced Development

NOV 28 1958

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6 ELECTROMECHANICAL components & systems DESIGN

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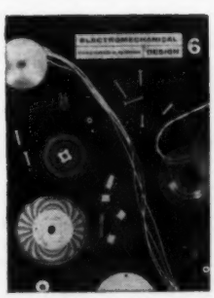

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←CIRCLE NO. 1 ON INQUIRY CARD

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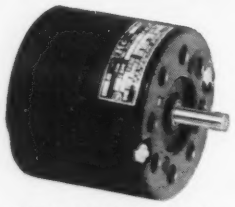
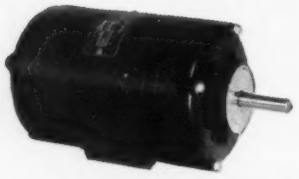
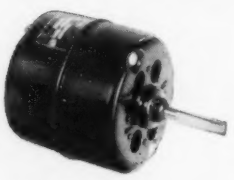


Model 2800 Illustrated
Shaded Pole Motors
1/2000 to ⅛ H.P.



Model 2900 Illustrated
Induction Motors
1/1400 to ¼ H.P.



Model 11A Illustrated
Universal and D.C. Motors
1/100 to ½ H.P.

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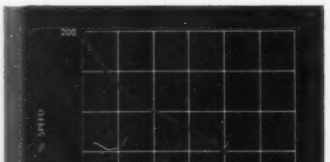
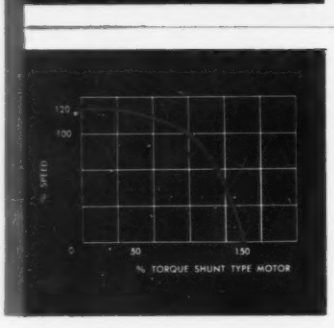
Through the years, designers and purchasing agents have learned that they can *depend* on Howard to *quickly* and *inexpensively* produce a motor to *any* specifications. With over 100,000 specs on file, chances are Howard engineers have worked on applications similar to yours—and can easily meet your mechanical, electrical and cost requirements. To aid you in selecting the right motor for a particular job, general characteristics of the basic Howard motor types are listed below. Whatever your needs, if you're in the market for power—check with Howard first.

CHARACTERISTICS AND TYPICAL SPEED TORQUE CURVES OF BASIC HOWARD FRACTIONAL HORSEPOWER MOTOR TYPES

UNIVERSAL MOTORS

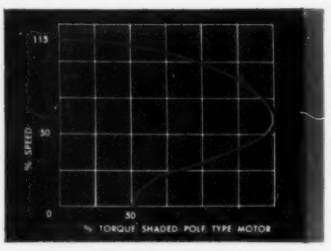


Series Type
Power: DC and AC 25 to 75 cycles.
1. High No Load Speed.
2. Full Load Speed (Optimum Performance) at approximately 50% no load.
3. Starting Torque high, 200 to 300% full load torque.
4. Variable speed, speed decreases with increasing loads.



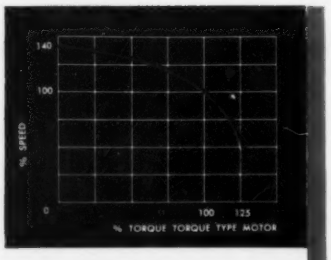
Shunt Type **Power:** DC only.
1. No load and Full load speed are adjustable by winding or by armature and/or field voltage control. Approximately a 2:1 speed range can be obtained by field control, and 10:1 by armature control.
2. Fairly constant Full load speed.
3. Regulation varies from 10% to 30% depending upon duty and power requirements.
4. Starting torque, approximately 150 to 200% of Full Load.

SHADED POLE MOTORS

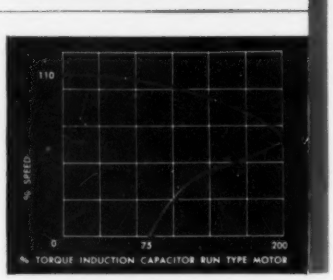


Power: AC 50 to 60 cycles.
1. No load speed is determined by the number of poles with a No load slip of 3 to 5%.
2. Fairly constant Full Load Speed, with a full load slip of 10 to 20%.
3. Breakdown torque approximately 150% of full load.
4. Starting torque low, 50 to 75% of Full load.

INDUCTION MOTORS



Torque Type
Power: AC 50 to 60 cycles.
1. No load speed is determined by number of poles, with a No load slip of approximately 5%.
2. Full load speed decreases with an increasing load. Designed to operate at approximately 30% full load slip.
3. No breakdown torque.
4. Startina torque high approximately 125% full load.



Capacitor Run Type
Power: AC 50 to 60 cycle.
1. No Load speed is determined by the number of poles, with a No load slip of 2 to 4%.
2. Constant full load speed, with a full load slip of approximately 10%.

Hysteresis Synchronous type
Power: AC 50 to 60 cycles.
1. Constant synchronized speed, determined by number of poles.
2. Starting torque equal to full load torque.
3. Quiet operation.

Reluctance Synchronous type motor
Power: AC 50 to 60 cycles.
1. Runs at a synchronized speed, determined by the number of poles.
2. Starting torque low, 50 to 75% of full load.

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Published monthly by Benwill Publishing Corporation. Harold G. Buchbinder, President; Milton Berns, George Palken, Vice Presidents, Robert M. Robbins, Treasurer. Executive, Editorial and Subscription Office: 1357 Washington St., West Newton 65, Mass. Telephone BIgelow 4-9006.

ELECTROMECHANICAL Components & Systems DESIGN is circulated without charge upon request to qualified research, development and design engineers in all branches of industry in the continental United States including governmental and university installations. Other subscriptions: Continental U.S., $10.00 per year; single copy, $1.00 when available. Copyright 1958 by Benwill Publishing Corporation. Accepted as controlled circulation publication at Orange, Conn.

Postmaster: send form 3579 to Benwill Publishing Corporation, 1357 Washington St., West Newton 65, Mass.

Ignorance Is No Excuse

Our editorial staff has been aware that patents are an important concern of electromechanical designers and should be given editorial attention. Tradition in technical magazines has been to report on selected new patents in those areas of interest to the readers. We have felt, however, that our readers are more interested in their own and their company's patents than in those of others which generally cannot be reported until they are outdated. If so, we reasoned, our readers would be more concerned with the general aspects of patent law related to their activities than with patent descriptions.

This reasoning led to a dilemma. Upon pooling the experience of our staff in the area of patent law, we found our combined knowledge amounted to profound ignorance, even though one of us had worked for many months next door to a very active legal office in a research and engineering company. How could we give editorial direction in a subject we knew so little about?

Confident that our readers would be at least as curious as we are about the activities and benefits of an engineering legal office we went in search of an authority to solve our problem not only by giving us the editorial direction but by writing the material as well. We consider ourselves fortunate to have found David A. Rich, a registered patent attorney, who has consented to be one of our staff columnists. Dave is not only a patent counsel, but a physicist, engineer, business man and philosopher.

For the past five years, Dave has been busily at work at Sanders Associates in Nashua, New Hampshire, as he says, eating, drinking, and sleeping inventions, patent law, licensing agreements, government contracts, trademarks, copyrights, corporation law, and tax law. Before that, he worked many years as an electronic design engineer in the fields of industrial controls, television deflection systems, telephone and dictating control equipment. During the war he fought the Battle of the Navy Radar Training Program in which he served as an instructor in the fields of radar, sonar, microwave transmission lines, oscillators, antennas, etc.

Dave has an interesting degree called B.Ph., which means Bachelor of Philosophy, and a BS in physics and mathematics from the University of Chicago and an LLB from the Boston College Law School. At the University of Chicago, he served for two years as a research assistant in the Institute for Nuclear Studies helping redesign and remodel the 30-inch cyclotron and chasing a positive particle around a cloud chamber. This experience, Dave says, proved to him that research work is its own reward,—so he went into industry.

In this month's issue, starting on page 4, you will find Dave's introduction to his column.

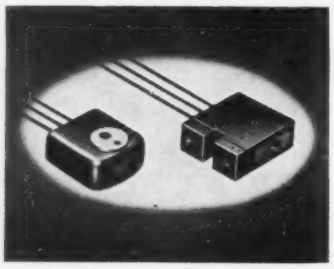
Robert B. Brotherston
EDITOR

READ AND RECORD HEADS

Specifically Designed for High Frequency, Non-Contact Magnetic Drum Applications

Type: **Librascope Models MH-10A, MH-10R-1, MH-15A, MH-10P. Read and Record Heads.**

Applications: **MH-10A is designed for general, non-volatile storage; MH-10R-1 for use in recirculating lines, with shielded coils eliminating crosstalk; MH-10P for clock reading; and MH-15A for general, non-volatile storage, providing greater peak-to-peak readback signal where increased record currents are available.**



Features: **Librascope has devised methods of accurately measuring ferrite core characteristics such as permeability, dielectric constant, coersive force and resistivity. Head coil characteristics of inductance, resonant frequency and magnetic field symmetry are also closely determined. Measurement of these characteristics assures superiority and uniformity of head performance.**

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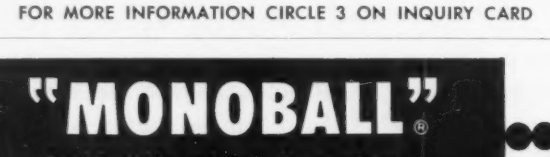

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FOR MORE INFORMATION CIRCLE 4 ON INQUIRY CARD

STAFF COLUMNIST

David A. Rich
Patent Attorney
Sanders Associates
Nashua, N. H.

CREATIVITY

The Identification and Protection of its Products

"I claim" is the typical phrase introducing a series of clauses at the end of a patent intended to be a precise statement of an invention. This column will be about patents; but do not be misled by the title. I claim that patents and related fields have far greater significance to technical people in industry than the mere statement of an invention. Of course, it is important to understand what an invention is. And we shall talk about it. But it is also important to set up routines, understand the need for collating technical information, analyzing it and evaluating its patentability. And we shall talk about this. It is important to file patent applications, prosecute these applications vigorously, and guide them warily through the horrendous maze constituting the archives of the Patent Office. We shall talk about this, too. We shall be concerned with the entire field of creativity and the identification and protection of its fruits.

We say that in our society, competition stimulates productivity, efficiency and wealth. Clearly then we must be on guard against unfair competition. But in our very Constitution we have set up the mechanism for granting monopolies. After all a patent is a monopoly. Under our law the patentee—the man who gets the patent—is granted a peculiar kind of property right by the government: the right to exclude all others from making, using or selling his invention. We have come a long way since our Constitution was written. Is the idea of protecting original ideas to benefit their creators outmoded? Or if these protections are important, why are they ignored by half the world? Ours is not the only patent system in the world. There are about as many systems as there are governments. A great deal can be learned about the philosophy of patents by looking into some of the other patent systems that have evolved. We shall talk of these things.

The business of protecting ideas, original designs, works of art, new machines and trade names is indeed murky. Somehow you feel it's just plain wrong for anyone to benefit unduly from another's original contributions, much less deprive him of its benefits completely. But what is the value of a writing to the writer, music to the composer, sculpture to the sculptor, painting to the painter, an ornamental design to the industrial designer, a new plant to the planter? And are all these values the same? How about protecting increased eye appeal for an article of sale, and what is it worth? What about the improvement—the very slight improvement—that makes an article more useful? How much is it worth; how much protection should it have? And what about the value of these things to the public, to business, to science, to art, to government, to you? We shall talk about these things.

"I Claim:"

In deciding the character of this column it occurred to me to include a regular review of the more important patents as they issue. Except for the relatively few patents of unusual interest, I have decided against this. Ordinarily, a patent issues long after the device has become well known. Although steps have been taken to speed up the processing, it still takes 3 to 5 years for a patent to issue from the time it was filed. By that time, if you haven't heard of the device, it's probably not tremendously interesting.

Another idea was to comment on court decisions in patent cases. But such comments tend to become fairly technical, and primarily of interest to other patent attorneys. Even so, where some case is of particular interest, a comment or two may be in order.

So much of the work on electromechanical devices is done on government contract for ultimate government use that it seems timely to start by discussing some of the peculiar problems arising out of such business.

INVENTIONS, PATENTS AND GOVERNMENT CONTRACTS

Infringement of Patent. If you happen to be doing some work on a government contract, why worry about infringing on other people's rights? Many don't. And, of course, so far nothing has happened to cause the infringer to regret his actions. It seems that if the government consents to the manufacture of goods, the infringer is really in clover. One of the more powerful tools for protecting a patent right is no longer available to the owner of the patent. In such cases the infringer cannot be stopped from making a patented article. In response to a threat from a patent owner, he might well say, "Go ahead, sue me," with the mental reservation, if you can. In response to his implicit reservation you might well ask, "What does he mean, 'if I can?'" But he's right. He only has to notify the government that you are trying to sue him for infringement and the government takes over the defense of the suit! How delightful for him.

You have a contract with the government granting you the exclusive right to prevent others from making, using or selling articles that infringe your patent. In return for this you have published the invention, telling others how to practice it. Normally when someone infringes on your patent, you go to court and the court orders the infringer to cease and desist from any further use of this patent. And that's not all. The court orders him to give you the money you would have made on the patent, or (for income tax purposes) the loss in value of the patent as a result of the infringement. But now if that someone infringing on your patent is working on a government contract, the government with whom you have the patent agreement takes up the defense of the infringer. A strange practice!

If the government successfully defends the suit, the infringer is essentially "off the hook." If the government

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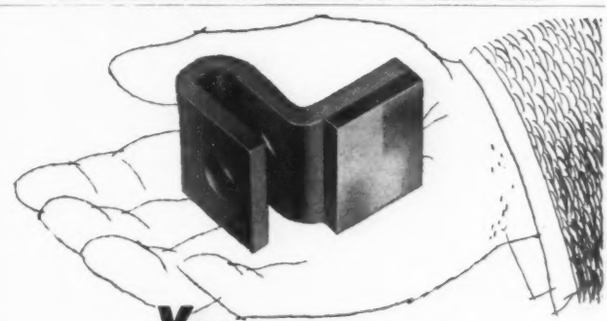

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FOR MORE INFORMATION CIRCLE 6 ON INQUIRY CARD

AUTOMATIC PRESSURE or VACUUM CONTROL J6

UE TYPE **J6**
PRESSURE & VACUUM CONTROL

UNITED ELECTRIC TYPE J6 unit is designed to automatically control either pressure or vacuum . . . has a fixed, uniform on-off differential as specified between limits of 3" WC to 2 PSI . . . and a maximum controlling pressure of 180 PSI. It is a sensitive, weatherproof, precision built control with good repeatability. Recommended for all pressure or vacuum applications which require close on-off differential control.

Switch Differential	Fixed as specified between limits of 3" WC to 2 PSI.
Switch Ratings	15 or 20 amps at 115 or 230 volts AC, also DC switches upon specification.
Switch Types	N.O., N.C., or Double Throw, no neutral position.
Size	4¾" x 4²⁷⁄₃₂" x 2⁵⁄₁₆".
Weight	Approx. 1 lb. 8 oz.
Electrical Connection	½" NPT conduit opening in enclosure, screw type terminals on switch is standard.
Enclosure	Die-cast aluminum case, black wrinkle finish standard.
Mounting	Surface mounted—by 2 mounting ears.
Bellows	Seamless brass—spring loaded.
Pressure Connection	¼" NPT female connection.

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loses, however, the infringer is liable for all costs involved. But these things are not easily settled. The average patent case, for example, takes 3 to 5 years to get up to the Circuit Court level and can take a good deal longer if appeal is made to the Supreme Court. Thus, the contractor's liability for infringement in terms of actual damages that he pays out of his pocket is fairly remote. The liability is there but he has suffered none of the normal misery involved in a lengthy and complicated judicial proceeding.

You might conclude from these statements that it's generally worthwhile to infringe patents in working on a government contract. But before you do let me tell you about a case where this sort of policy led to considerable embarrassment. Two men bid to the government to supply the same office furniture. One of them held a patent on the particular item to be made and the other knew it. The man who didn't have the patent got the contract. When justice caught up with this contractor, he had to pay not only the usual damages but punitive damages for wilfully having infringed a patent. This incident would suggest that a general policy of infringing on patents in working on government contracts is risky.

Rights as Against the Government. Another interesting facet of doing business with the government involves the protection of a contractor's patent rights as against the government itself. Suppose that the government gives you a contract to manufacture an article to government specifications, usually termed a "fixed price" contract. This implies that you the contractor agree to, and do, bid on the contract for a definite price, and the government, for the purpose of the contract, does not look into the details of the contract. The situation sounds fairly straight forward. But suppose you have a patent on the particular item to be manufactured and some "know–how". Suppose further that in making this item you introduce a few changes. Who owns the invention under these circumstances? It turns out that unless the contracting officer has sneaked one over, you own all the rights to such improvements.

But there's a real knotty area here. Let's assume that you have a patent or an application for a patent on a device that can be modified for government use. You face two possible alternatives: You can sell the government X number of units for a fixed price with no patent problems, or you can get a research and development contract to modify the unit to meet the standards of the military application. But when you do the latter, you get into the very difficult area of who owns what, patent–or improvement–wise.

Ordinarily it's reasonable to expect that when someone pays you to do some work for him he not only owns the thing you do but also any ideas that you may contribute to its improvement. When a company hires a man to work as an engineer, there is generally no question in anybody's mind that anything he develops while working for the company belongs to that company.

Similarly, the government has a vested interest in patent rights. It does not want to be in a position of being unable to have other manufacturers produce the item for which it has paid the development costs. At the same time, however, it wants the contractor to be happy to do government work and come up with new ideas.

The philosophy of what the government's role in this area *should* be is controversial and will be a subject for comment in the future. For the present, however, I would like to discuss what appears to be the current policy.

An invention in government contract parlance is any improvement or discovery first conceived or actually reduced to practice in the performance of work called for or required under the contract. An inventor's right to his invention is complete. In general he owns the invention unless he contracts away part of the right. This is true

even with regard to the government. For this reason in every research and development contract the government has a special patent rights clause directed to this problem. In order to protect the right of the government to practice or have practiced the invention for government purposes, the government must have a license. Ordinarily the government blanketly requires the contracting officer to include a standard patent rights clause under the Armed Services Procurement Regulations, giving the government the necessary protection in practicing any invention of this character. In all such contracts, then, the government reserves a royalty–free, non–exclusive license to practice or have practiced all such inventions for governmental purposes.

Note, however, that even where the government does get a license, the contractor reserves the commercial rights in the invention. As a matter of fact, in the usual clause on patent rights these days, there is a sentence included stating in no uncertain terms that no license is granted to the government to use the invention for providing services to the general public in competition with the contractor or his licensees.

If, then, it is possible to retain the commercial rights to the invention, why bother about having or retaining title in the invention as against the government. A tough question! *I claim* that it's a good idea even as against the government.

First, if the government goes ahead and uses the invention in the face of clear title in the hands of the contractor, the government must pay reasonable royalties as defined by the Court of Claims. Thus, there is an avenue available to obtain compensation from the government for unlicensed use of a patented invention.

Second, there is no question that there is an excellent psychological advantage in having a proprietary patent position. This stems from the plain, ordinary moral integrity of most of the government contracting officers and the feeling on the part of the Defense Department that the fellow who makes a contribution should be in some way rewarded.

As a practical matter, patents are recognized by the Defense Department agencies. The extent to which this recognition is accepted by individual employees varies enormously; however, there is no question but that it is advantageous to develop and assert a proprietary position if it is at all possible.

Third, the reputation gained by the individual contractor who does have many patents in areas of government or military interest is of no little significance. A large number of patents clearly categorize a contractor active and able.

Let's assume for the moment that it is advantageous to go about obtaining rights against the government and let's look into the problems involved. At one time terms like "foreground" and "background" inventions were used. These terms have been eliminated from the current literature but they are perhaps most useful in depicting the character of the problem. A *background* invention is generally a patented invention conceived and actually reduced to practice at the expense of the contractor prior to the initiation of a contract. As a rule it applies to a standard commercial item. The term "background" thus implies that the contractor had, before entering into the contract, all of the rights to a patentable invention completely defined. A *foreground* invention is one first conceived or actually reduced to practice in the performance of work called for or required under the contract.

A contracting officer *may* exempt from the patent rights clause inventions covered by an issued patent or an application for a patent filed *prior to the award of a contract*. But it is pretty clear that the contracting officer is going to take no action in this area unless the problem is raised by the contractor. After the award of a contract has been

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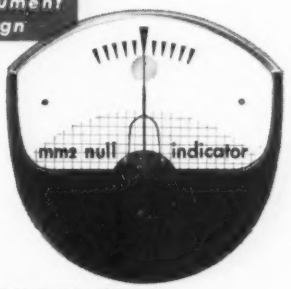

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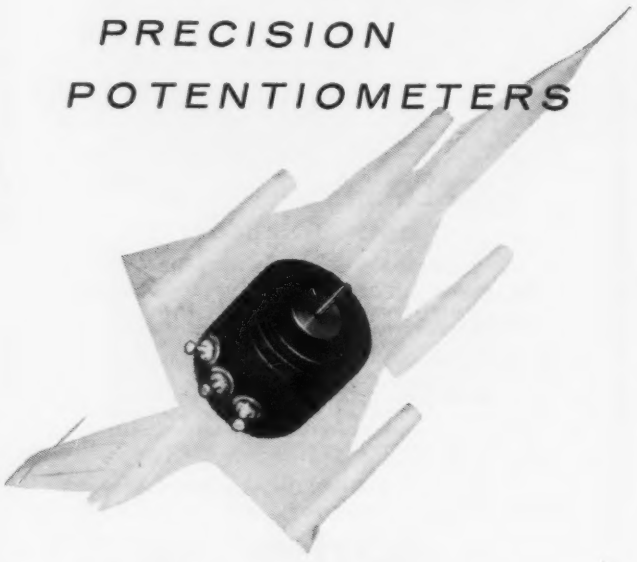

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FOR MORE INFORMATION CIRCLE 10 ON INQUIRY CARD

made, at the time the detailed terms are negotiated, the contractor may take exception to the operation of the patent rights clause relative to certain enumerated inventions. Where appropriate, the contractor is well advised to take such an exception. Once the problem is raised the contracting officer has in his discretion the power to grant the exception. Without a patent or patent application, it is difficult precisely to define the character of the invention in which the contractor claims a proprietary interest. A patent or patent application thus becomes an important document in establishing the contractor's proprietary position.

There are four exceptions that operate in favor of the contractor when he has an invention conceived before the contract, but not completely built, tested or successfully operated, or, as is known technically, "actually reduced to practice".

- The first involves the expending of sums by the contractor for research and development and such expenses as the preparation and prosecution of patent applications that are relatively large, compared with the applicable amount of the contract. This exception is very unclear and little has come up in administrative proceedings to cast any light on just what it means.
- The second exception involves establishing the practicality of the invention, for example, by engineering design. This is a good one to use. It means that where detailed drawings have been prepared for the device covered by the invention, there's a good basis for obtaining the consent of the contracting officer to an exemption. For electronic devices, for example, an adequately detailed schematic circuit diagram is generally sufficient to establish the engineering design.
- The third exception involves inventions that cover basic materials where it is not the purpose of the contract to develop such materials. A good example of this sort of thing is a material such as Kel–F, developed by M.W. Kellogg Company. Recognizing the value of using Kel–F. the government may well desire a company like Kellogg to develop other products having improvements dependent upon the characteristics of Kel–F. But if M.W. Kellogg Company has, in fact, developed this material with its own money, the government has no ground for any rights to it.
- The fourth exception is fairly unique and applies primarily to universities and non–profit institutions. In this case, the invention is useful only for military purposes and the contractor has no facilities for producing the device desired.

FOREIGN PATENT RIGHTS

An important but generally overlooked patent area is that of foreign rights to improvements resulting from the performance of government contracts in the United States. Ordinarily the United States Government is not interested in foreign rights to patentable inventions and these rights are rather easily sold. Indeed they have a great value. Of course, one gets into complications where the invention covers a device that is classified. But these things are not insuperable. There are mechanisms set up whereby even classified devices or classified inventions can be practiced.

I should like to say categorically that there is gold outside this country in technical know–how. Most foreign countries are willing to pay for technical know–how whatever form it may take. This is not only a national attitude but also the attitude of the individual companies. In general, although foreign countries do not have the dollars to buy the devices covered by this know-how, frequently restrictions on transfer of dollars do not apply where technical information is involved. This is indeed an attractive and happy area for discussion, and–yes, we shall talk about it again in the future.

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HI-TORQUE ACTUATOR MOTOR

Converts Armature Vibration of an A-C Operated Solenoid to Rotary Motion

An actuator motor that is neither a true motor nor a true solenoid but includes some of the features of each is expected to fulfill many design requirements for a prime power source or a power servo unit. A typical unit weighs only 10 ounces yet delivers up to 10 inch lbs of torque at 15 rpm for about ¾ ampere input at 115 volts. Its high starting torque combined with extremely rapid stopping characteristic, its ability to operate efficiently from 60 cycles, 400 cycles or d-c pulses and its light weight make it a unique and versatile device. It can deliver maximum torque when operated from 2 millisecond d-c pulses and can remain in a fully stalled condition without harm. Figure 1 is the torque-speed curve of the unit for 400 cycle operation.

DESIGN DETAILS

The actuator motor, designed and manufactured by The Viking Tool and Machine Corp., may be described as a rotary solenoid with a dynamically stable armature vibrating at a rate of 120 cycles per second when operating from a 60 cycle power source. The vibratory motion consists of a power drive stroke and a return stroke. Major portion of energy from the power drive stroke is used for output torque; the remaining portion is stored in a pair of balanced springs to drive the armature on the return stroke. This full cycle takes place within each half of an a-c cycle. Output torque is transmitted from the armature during the power drive stroke through a unique, extremely rapid action, one-way clutch to the output shaft. The motion at the output shaft is, theoretically, a very rapid start-stop pulse ouput. Actually, under very light loads, the inertia of the clutch and output shaft is sufficient to cause practically uniform rotary motion. Under heavy loads or with the addition of detenting action, the motion will be a stepping type wherein the full torque is delivered and complete stopping is obtained within each one half of an a-c cycle. Because of the vibratory (or dithering) motion the starting

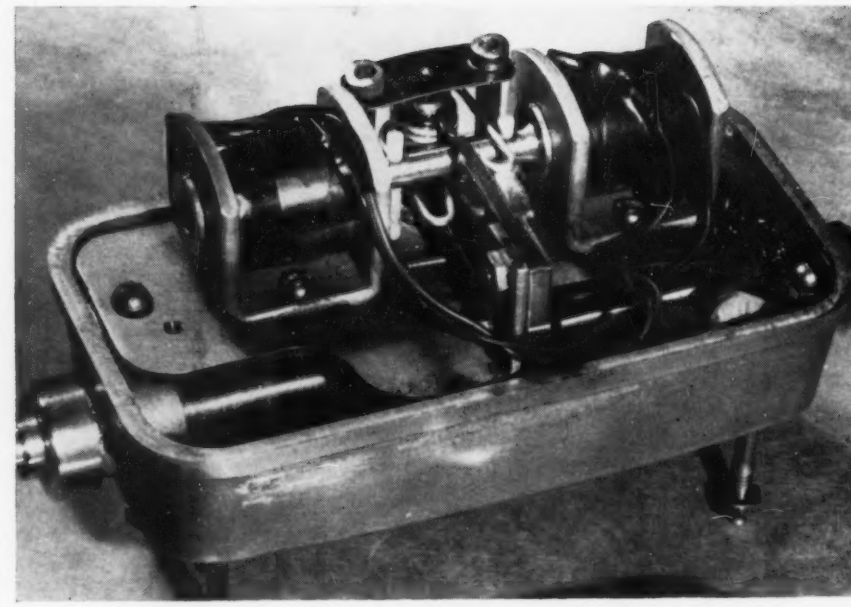

Fig 2—Early model of actuator motor for TV antenna application.

Fig 1—Torque-speed curve of the actuator motor for 400-cycle, 115-volt, ½-wave-rectified operation. The presence of one or more knees in the curve is an odd feature of this basic design. The curve says that the load on the motor can be increased without any reduction in output speed. In other words the efficiency of the motor actually increases at certain points as the load is increased. The reason is that as the motor is loaded, the armatures' vibration amplitude decreases, causing the armature to vibrate in a different more efficient portion of the magnetic field.

Fig 3—Intermediate model of actuator motor designed to drive coaxial switch.

Fig 5—Clutch assembly of the Viking actuator motor. It is actually the equivalent of a mechanical either-or circuit wherein rotation of either shaft 1 or 2 creates a direct geared output at 3. Rotation of both 1 and 2 causes 3 to rotate at the speed of the faster moving input. This clutch device is capable of responding to inputs of better than 400 pulses per second.

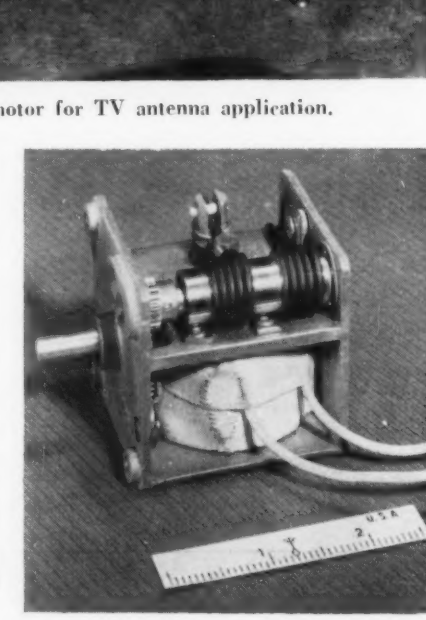

Fig 4—Final model of Viking actuator motor.

torque and the running torque of the motor are equal.

Small angular motion of the armature permits operation within the most efficient part of a solenoid's stroke. A small constant air gap makes possible high torque from comparatively low input currents.

BACKGROUND OF DESIGN

To explain the motivation for development of this device, we have to go back several years to the time when motorizing TV antennas was a large business. Using a vibrating solenoid in conjunction with a clutch mechanism was conceived as a means of developing the high starting torques necessary to crack the ice accumulation at the mast juncture. The end result of this development is illustrated in Fig 2. It consisted of two opposed a-c solenoids with a common spring loaded plunger, and a shaft with a wrap around spring mounted at right angles to the solenoid plunger. Depending upon which solenoid was energized the plunger bar would not only vibrate but would be slightly displaced toward the energized solenoid. In this way one of two pins on the plunger shaft would vibrate against one or the other of the clutch spring ends, creating incremental rotary motion. This unit was reversible; direction of rotation depended upon which solenoid was energized.

The antenna rotator field soon became so highly competitive that this device could no longer compete and the project was shelved. The reversing feature, using a spring clutch, was very critical and also caused a bulky motor configuration.

Some time later Viking needed a spark free, high starting torque, rotary device to drive a coaxial switch. They dropped the reversing feature of the first design and reproportioned and packaged the unit. They added a second clutch spring with one end secured to the motor housing. This acted as a brake to prevent back slippage as the plunger and clutch spring were being returned for another stroke.

Viking built several thousand of these motors for this application and sent out design releases. The response indicated the need for such a device, but it also indicated the unit was too expensive, noisy, short lifed and inefficient—1.8 amps @ 115 V was required to develop 6 inch lbs. at 10 rpm. In short, everything was wrong with the design except high starting torque and rapid stopping.

A new requirement for a rotary device to drive a coaxial switch but at a lower torque level brought about a third design aimed at eliminating the shortcomings of the second. Designers replaced the plunger type solenoid with a rotary type armature and the wrap around spring clutch with a roller type clutch. They also replaced the spring that lifted the plunger and clutch spring for another stroke with a rubber bumper that bounced the armature back for another stroke. The bumper worked well until they tried to operate it at low temperatures. They tried a silicon rubber bumper but satisfactory low temperature operation was still impossible. Finally they replaced the rubber with the pair of balanced springs presently used.

As this design was finalizing, demand for a high torque drive for a coaxial switch recurred, but this time with the added requirement of continuous duty cycle. The design, satisfying this requirement, develops torques of eight inch lbs. at 10 rpm, and can operate over a wide temperature range and on a continuous duty cycle. This motor is the same as the final version of motor except for the use of die cast front, the addition of an idler gear for lower speeds and a drive and brake clutch (Fig. 4).

Mr. E. W. Bossi, in describing the motor design, said, "We feel that the clutch constitutes a product in itself. Designing it to operate at 400 cycles a-c for electrical and hydraulic switching applications in aircraft was one of the difficult problems. The final clutch combines extremely low inertia with a carefully selected combination of roller pressure angle and wedging spring force. We have also perfected a compact roller clutch capable of converting vibratory motion into bi-directional rotary motion."

Although the actuator motor provides continuous rotary motion it is not a true motor, and therefore should not be considered as a substitute for a continuous running motor. The functions are limited to short life or intermittent duty applications and generally a continuous operating life of over 250 hours is not recommended, however this limitation will vary depending on output torque required.

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MISSILE ENGINEERING

The "collapsing of time" concept has taken on added significance as a result of the current international situation. In Tucson, Arizona, Hughes has established the Tucson Engineering Laboratory for the purpose of shortening the elapsed time between missile development and its effective tactical use. This activity, established over 2 years ago, has proven that the quasi-simultaneous development and production of missiles can become a feasible reality.

The Tucson Engineering Laboratory is now expanding its scope of operations. Mechanical Engineers, Electrical Engineers, or Physicists who like to work on urgent problems and who have the ability and enthusiasm to constantly improve the product and its reliability, will find this an ideal environment. Specific areas of interest include: missile system analysis, infrared and radar guidance systems, electromechanical and hydraulic control systems, missile and test equipment and electronic circuit design.

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CIRCLE 12 ON INQUIRY CARD

DIGITAL, ANALOG, HYBRID SHAFT-ANGLE INDICATOR WITH FRICTIONLESS "OPTICAL GEARING"

FIG 1—End view of Optisyn, showing 4 phototransistors directed at light-reflecting prisms mounted above 2 ruled disks.

Here is an electromechanical device employing novel optical techniques to convert shaft motion into a triangular waveform that can be integrated digitally, measured analog-wise or used in a hybrid analog-digital measuring system. Its accuracy of measurement can be better than one minute of arc even for high angular input rates. As a servo component it constitutes a new design technique with distinct advantages for control. It accomplishes the effect of gearing without gears, compensates for its own mechanical eccentricities and makes possible complete input-to-output load isolation.

A simple, compact shaft angle indicator designed for digital pickoff of velocity information in gyro-integrating-accelerometers has been discovered to be a very versatile type of instrument for measurement and control. Invented by Harold H. Seward at the MIT Instrumentation Laboratory for use in inertial navigation systems, this new instrument called an Optisyn (Fig 1), accomplishes frictionless optical gearing, is extremely precise, minimizes inertia and wear, yet is rugged mechanically. Realizing the many possible applications for this type of device, Dynamics Research Corporation of Woburn, Mass. has developed a general purpose Optisyn that operates on a-c or d-c excitation in analog, digital and hybrid systems. The basic structure and operating principles of the DRC design are described in Figs 2 and 3. Figure 4 shows how Optisyn principles can be applied to translatory position indication as well as rotational. Figure 5 describes circuit connections and output waveforms for single-phase and two-phase operation of the unit.

OPTISYN STABILITY

For two diametrically-mounted and interconnected transistors, the net output voltage goes positive or negative depending upon whether one or the other transistor receives more light from the rotating pattern. When the two interconnected transistors receive equal illumination (each at the half-illumination position, see Fig 3), a null voltage will result which is as good as the matching of the transistors. If ambient temperature or supply voltage changes, each phototransistor is affected equally and the null remains true.

The null voltage is also stable even if the two disks are not precisely concentric. This is a significant feature of the DRC Optisyn, since initial alignment and maintenance of concentricity have been limiting factors in the accuracy of nearly all shaft- position encoders. In theory, eccentricity as great as a half-sector-width can be tolerated; but a practical, and easily achieved, limit for Optisyn eccentricity is that which causes the half-open sectors to change by $\pm\frac{1}{4}$ of a sector at the radius of the phototransistor.

Another advantage of the cascode transistor circuits is their stability at higher operating frequencies. When a single transistor is used in series with a load resistance, the average value of the waveform shifts off null at the higher frequencies. This shift is due to the rectifying action of minority carrier storage which causes the transistor to increase its current faster than it can decrease it. With the cascode circuit, this effect is diminished and the waveform is symmetrical about the null.

DIGITAL, ANALOG, HYBRID

The clean triangular wave output of the DRC Optisyn lends itself to a simple digital pulse counting operation. Optisyn systems of a *digital* nature result from counting rotations of the interfering light pattern. A binary output can be interpreted directly from the positive and negative polarities of the d-c waveform. The cascode phototransistor circuit of Fig 5 forms a portion of the digital Optisyn system of Fig 6. The four linear segments of the Optisyn waveform offer tempting analog possibilities, particularly with their ambiguity removed by a two-phase relative polarity sensing circuit.

In one experimental Optisyn system, for example, it was found possible to read the linear waveform to within $\pm 5°$. This accuracy combined with an optical gearing of 512:1 resulted in a shaft angle accuracy of better than 1/30,000 of a revolution.

When an Optisyn is used to actuate a motor, a synchro, or another Optisyn, a pure analog form of operation results.

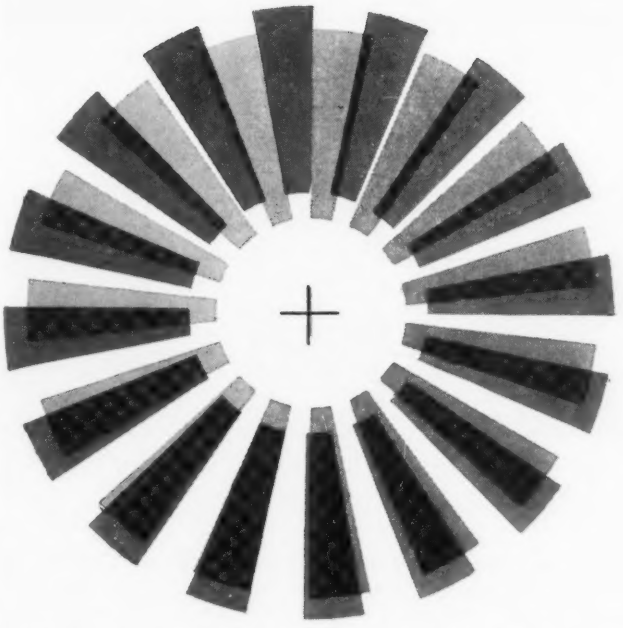


FIG 2—The Optisyn uses two transparent disks having photographic patterns of alternately opaque and clear sectors. One disk has one more (n+1) opaque and transparent sector than the other, resulting in the interference pattern illustrated.

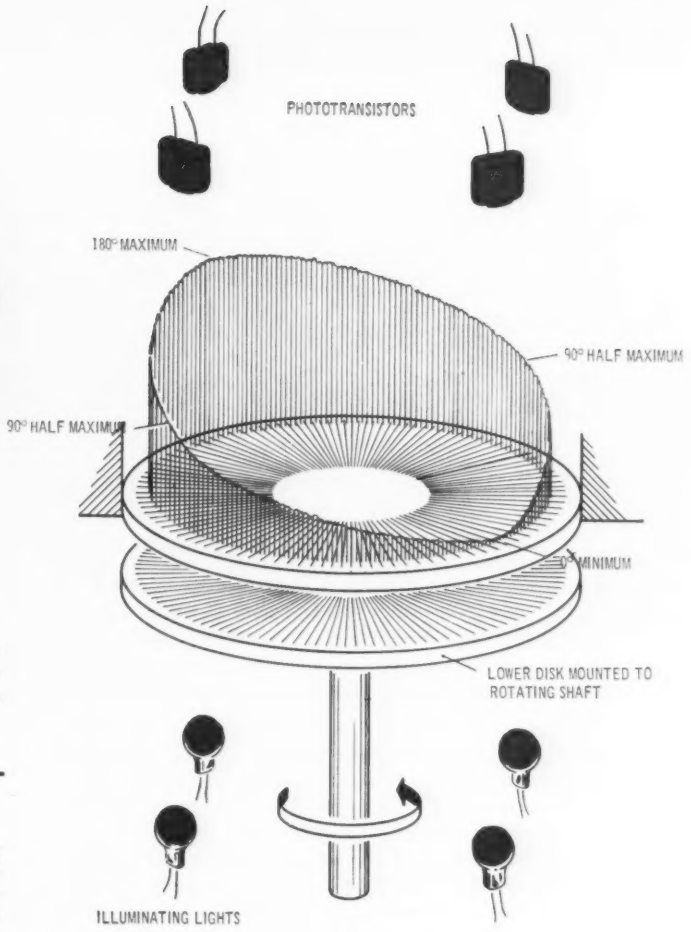
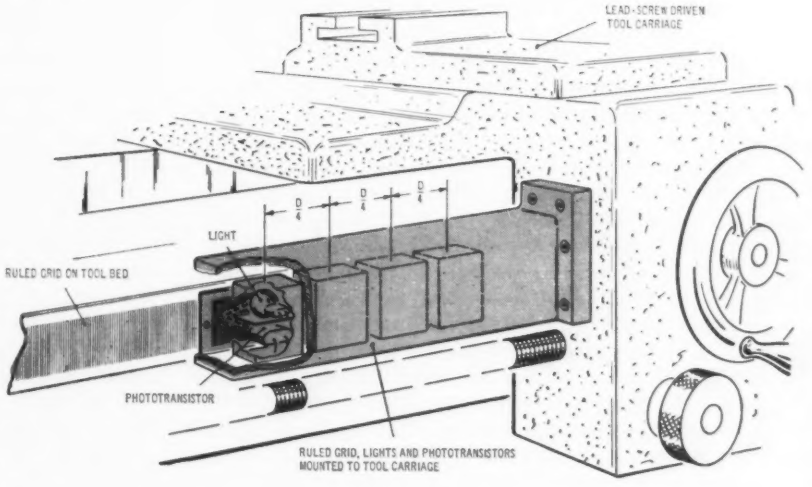


FIG 3—The two disks illustrated in FIG 2 are mounted concentric to the Optisyn axis of rotation, with one disk fixed to the case and the other mounted on the input shaft. In the standard 2-phase Optisyn, shown schematically, four lamps are located in quadrature on one side of the disks; four corresponding phototransistors are mounted in alignment on the other side. In operation the lamps transmit light through the interfering disk patterns to the phototransistors. For a given relative orientation of the disks, a minimum of light will be transmitted in one region around the disk circumference. At 90° either side of this region of minimum light, the clear sectors will be half open, and at 180° the clear sectors will be aligned and completely open for maximum transmission of light. If the Optisyn shaft is rotated by an amount equal to one sector angle, the dark and light transmission regions rotate 180°. A full rotation of the movable disk causes the dark and light patterns to rotate n times, n being the number of opaque lines on the rotating disk. The optical light pattern is thus "optically geared" to the input shaft with a magnification ratio of n.

FIG 4—Schematic of translational Optisyn for converting lead-screw drive to accurate digital control. A fine grid can be printed on a lathe bed having n lines per defined interval D. A second grid with (n+1) lines per interval D can be mounted to the tool carriage so that it moves in adjacency with the fixed scale. Two pairs of light and photo-transistor combinations can be mounted with D/4 spacing and made to operate on the basis of reflected light. As the tool carriage moves, the same triangular waveforms as in the rotary Optisyn will be generated and can be used in either analog follower systems or digital position counting systems. Rotary DRC Optisyns could be used on the lead-screw drives, but the translatory form of Optisyn has the distinct advantage of eliminating errors due to lead-screw backlash, wear and loading deflection. Also, by using reflected light, the installation is simplified and an existing machine can be readily converted to precise digital control.



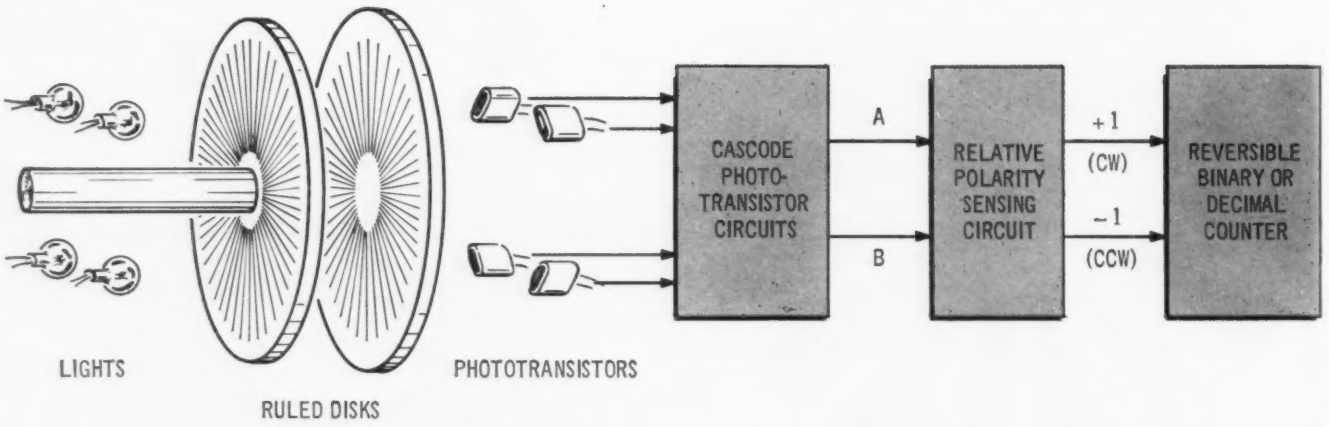


Fig 6—DRC Optisyn and associated circuit elements for digital application. Shaft angle position is determined digitally by integrating the relative polarity transitions of the two rectangular waveforms (A and B) in the reversible counter shown. 4-transistor Optisyn system can distinguish, by digital logic alone, increments of one-quarter revolution of the interfering light pattern. Optisyn resolution thus becomes ¼ n part of a revolution or 360/2048 degrees for a ruled disk having 512 lines.

As is shown later, the Optisyn is merely driven to a null condition in standard servo fashion, but full advantage is taken of the n-times optical gearing-up or gearing-down effect and the high inherent position constant.

Since the null crossings of the waveforms are always available while the Optisyn is operating in the analog mode, the unit lends itself naturally to hybrid forms of analog-digital systems. No analog or digital conversion devices are required for the input or output. Two or more separate ruled tracks can be placed on a pair of Optisyn disks, and each track can be independently used in analog, digital or hybrid systems.

OPTISYN SERVOS

For servo applications of the Optisyn, it is possible to use the Optisyn output waveforms for direct power drive merely by amplifying the output of the phototransistors. One method is obviously to insert an amplifier between the output signal and the load. Another is make each transistor a compound transistor as shown in Fig 7.

Optisyn servo systems appear to have distinct advantages over many conventional servos. Since the Optisyn output is optically generated, no back-emf is produced, as in the case of synchros. Optisyn output is independent of speed, and full torque can be applied at the lowest rates of motion.

Conventional servomotors of the induction-type must usually be geared up from the output shaft to provide an efficient torque characteristic. As a result, frequency response is greatly impaired since rotor inertia is increased by the square of the gear ratio. The usual problems of gearing—backlash, wear, space and cost—are also suffered.

An Optisyn with power drive output, however, can control a torque motor directly, thus eliminating gearing. In addition, the back emf generated in the windings of an optisyn-driven motor is essentially eliminated since the compound phototransistors behave as current sources. As long as the induced voltages do not exceed the supply voltage, they have essentially no effect on servo operation. Constant speed control over extremely wide ranges can be easily obtained since, in this mode, the motor drive acts as a synchronous motor operating at a variable, but precisely controlled frequency.

The compact physical form possible with a complete Optisyn-resolver repeater servo is illustrated in Fig 8. This single integral unit replaces the repeater synchro, the control transformer synchro, the servo amplifier, the servo motor drive, and the gear train normally employed. The saving in space, cost, and power requirement is apparent; and operational reliability in increased by the simpler instrumentation in a single package. One d-c excitation voltage powers the Optisyn, the power drive transistors, and the 2-phase resolver drive motor. Output shaft rotation will be shown to follow the 2-phase input command signal from a transmitting Optisyn for analog-to-analog shaft positioning, or from two flip-flops for digital-to-analog positioning.

Shaft Follower Servos. Several types of shaft servo systems are attainable with the DRC Optisyn. A simple form is the shaft follower servo shown in Fig 9.

To achieve an effective mechanical gearing by the factor n, where n may be as much as several thousand, the scheme in Fig 10 can be used.

Other gearing arrangements, such as differential gearing and gearing down, can be achieved by rotating and servo-driving various combinations of the two disks and the lamp-phototransistor assembly.

Remote Shaft Position Transmission. For the electrical transmission of shaft position, one or more 2-phase Optisyns can be slaved to an identical master Optisyn at a remote location as described in Fig 11.

Fine-Coarse Systems. For shaft driving applications, it is possible for 2 Optisyns to be pulled out of angular synchronism, or "unlocked", so that a constant error angle exists between them. To avoid this possibility, the fine-coarse technique so common in synchro usage can be employed easily with DRC Optisyns.

Two tracks of ruled grids are used in the Optisyn disks, with a set of single-phase or two-phase phototransistors and lights for each track. The number of sectors on the coarse track is made an integral submultiple of the sectors on the fine track so that a coincidence of nulls can occur, as in Fig 12.

Three or more optical tracks can be provided in an Optisyn for special forms of control. Unlike any known fine-coarse synchro system, however, the Optisyn requires no gear trains to achieve its multi-speed effect.

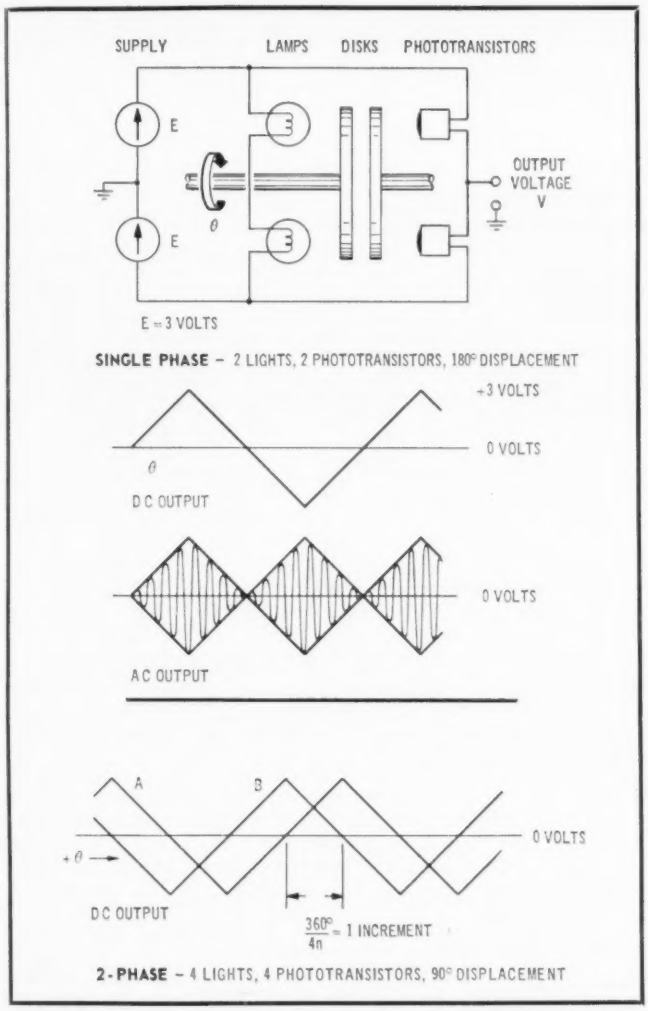


Fig 5—Waveform outputs for single-phase and 2-phase Optisyns. If a d-c voltage supply is used to excite the Optisyn unit, the output waveform will be of triangular shape. One pair of illuminated phototransistors produces a single waveform with positive and negative phases. Two pairs of phototransistors, mounted in quadrature, produce two triangular waveforms 90° out of phase as shown. If an a-c supply is used, the same waveform will be produced in the form of the envelope of modulation. The a-c output signal is similar to that of an ordinary synchro except that the modulated envelope is triangular rather than sinusoidal and, more important, occurs n times per revolution rather than only once.

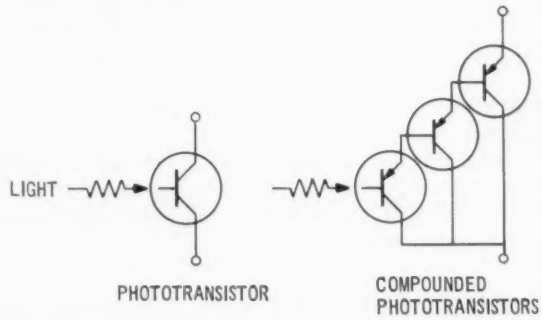


Fig 7—Compounding transistors for power gain capable of direct motor drive. Compounding is done by simply connecting the emitter and collector of a transistor to the base and collector, respectively, of a second transistor. A large power gain can be accomplished in this way; even greater gain is possible if the compounded transistor is again compounded with a power transistor. When phototransistors are used in the cascode circuit, the described conditions of null stability still hold.

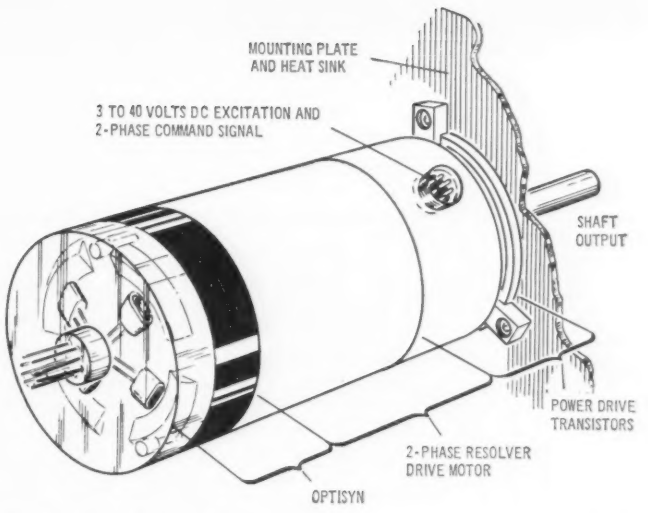

MOUNTING PLATE AND HEAT SINK
3 TO 40 VOLTS DC EXCITATION AND 2-PHASE COMMAND SIGNAL
SHAFT OUTPUT
POWER DRIVE TRANSISTORS
2-PHASE RESOLVER DRIVE MOTOR
OPTISYN

Fig 8—Complete Optisyn-resolver repeater servo in a single self-contained package.

OPTISYN-RESOLVER SERVOS

By combining the resolution capability of the DRC Optisyn with the torquing capability of a resolver, a new class of servo systems is possible. The resolver is essentially a motor wound with a two-phase stator and a two-phase rotor as illustrated in Fig. 13. If the two Optisyn waveforms are applied to the two stator windings, the resulting magnetic field will rotate as shown. A complete rotation of the field will occur for each opaque sector on the rotating disk of the Optisyn. The direction of rotation will also follow that of the Optisyn.

If a constant excitation is applied to one rotor winding, a rotor field vector is also produced. This rotor field interacts with the stator field and creates a torque that will turn the rotor until the two vectors oppose one another. Hence, for one rotation of the Optisyn, n rotations of the resolver will occur. The maximum correction torque occurs when the resolver shaft is 90° from null. If the other rotor winding is shorted through a variable resistance, a simple and effective damping control is attained by induction motor action.

A gearing of other than n:1 can be obtained if a second Optisyn is coupled directly to the resolver shaft. By feeding the waveforms of the second Optisyn to the two-phase rotor, in place of the constant excitation, the rotor field will rotate once per opaque sector in the same manner that the stator field rotates with the former Optisyn. As before, the rotor will be torqued until the two fields are in opposing direction.

The gear ratio from input to output shaft can be seen to be $n_1:n_2 \pm 1$, where n_1 is the number of sectors on the stator Optisyn and n_2 the number on the rotor Optisyn. The ± 1 factor depends upon whether the rotor field is connected to rotate in the same (+) or opposite (−) direction as the rotor motion. The maximum correcting torque is of the same magnitude as before, but occurs when the rotor is displaced from null by only $90°/(n_2 \pm 1)$. Hence, although the gear ratio has ben reduced by $(n_2 \pm 1)$, the stiffness of the servo has been increased in the same proportion.

If the rotor Optisyn is disconnected from the rotor shaft and allowed to operate independently in the same manner as the stator Optisyn, a differential system results. The resolver will make one complete revolution each time the net rotations of the two Optisyns differ by one opaque sector. Optisyn-resolvers can also be cascoded to achieve effective gearing-up or gearing-down by the factor n^2.

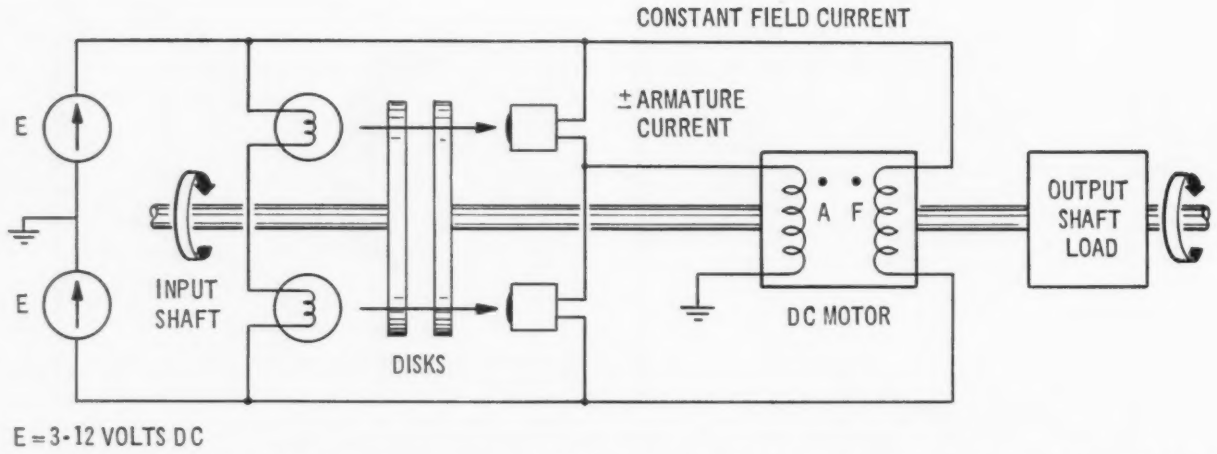


Fig 9—A simple Optisyn shaft follower servo. An input shaft drives the leftmost disk, causing the light pattern to rotate slightly and unbalance the voltage drop across the phototransistors. This, in turn, results in a positive or negative increase in armature current through the d-c motor. The resulting torque drives the output load and disk until balance is restored. It will be noted that the load is completely isolated from the input shaft. The mechanical coupling ratio from input shaft to output shaft is n/n+1 or nearly unity, where the input disk has n opaque sectors.

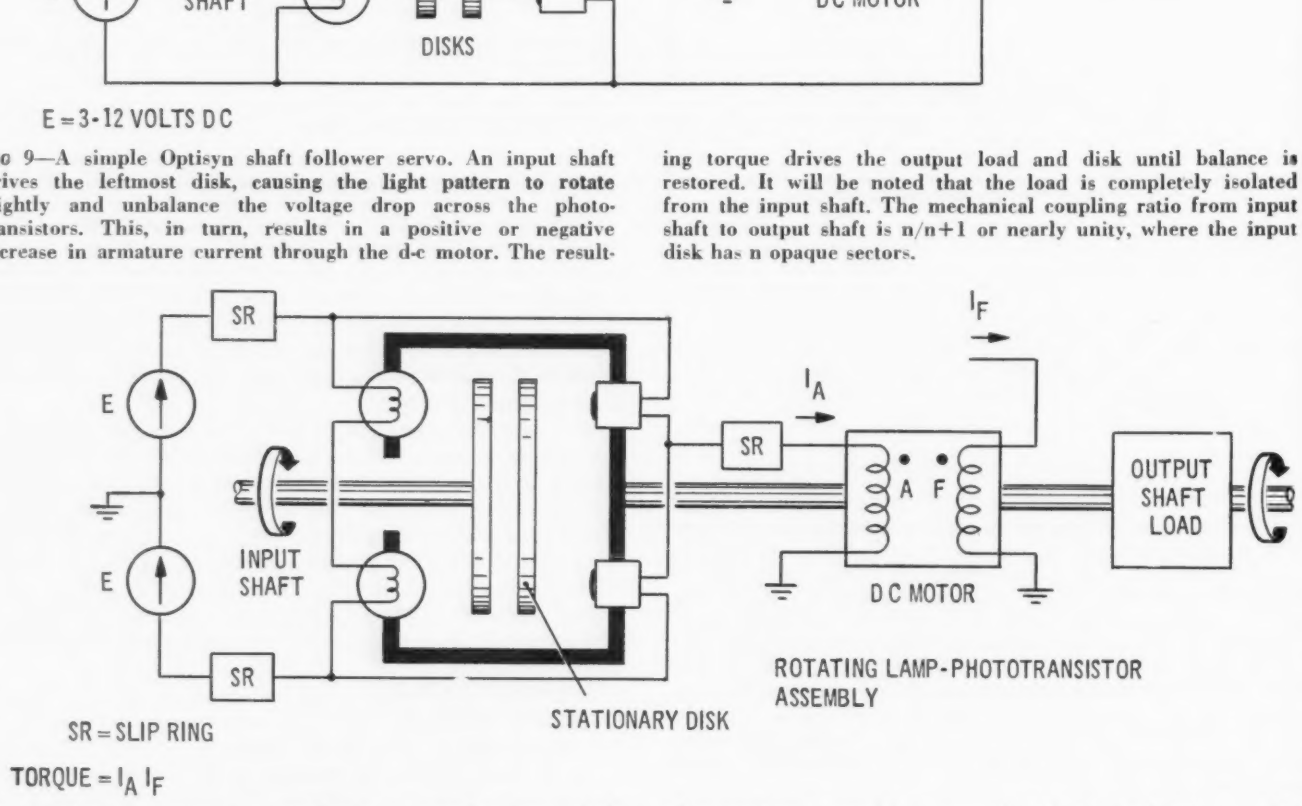


Fig 10—Optisyn servo for gearing-up or gearing-down shaft motion. In this arrangement, the output disk is held stationary instead of being rotated. To null the output voltage, the lamp-phototransistor assembly is rotated, with the load being coupled directly to this assembly. Such application produces high gear ratio without inertia, backlash, wear, space requirements.

DIGITAL TO SHAFT POSITIONING

A simple and versatile digital-to-shaft converter is possible with the Optisyn-resolver combination. A rotor Optisyn is coupled directly to the resolver rotor, as in Fig 14. Each stator winding is excited by a power flip-flop which provides a constant current excitation of either polarity. Each one of the four possible combinations of these two flip-flops will position the stator field at a particular 90° position.

During operation, a pulse representing a positive increment can trigger the flip-flops to rotate the stator field forward 90°. A pulse for a negative increment can rotate the field backward 90°. Such pulsing would cause maximum torque to be applied to the rotor to turn the Optisyn until the rotor field moved 90° to null. Since the Optisyn need only turn $90°/(n\pm1)$ to reach null, extremely accurate positioning can be accomplished without resorting to conventional servos.

In comparing this device to a conventional stepping motor, it is obvious that much smaller angular steps may be taken, thereby allowing higher frequency stepping rates with considerably more power.

TACHOMETER APPLICATION

A natural application of the Optisyn is in speed measurement. Even at very low speeds in the fractional rpm region, a relatively high frequency will be generated at the Optisyn output. By applying this to a simple frequency meter, a precise measurement of shaft speed, or differential shaft speed, is possible.

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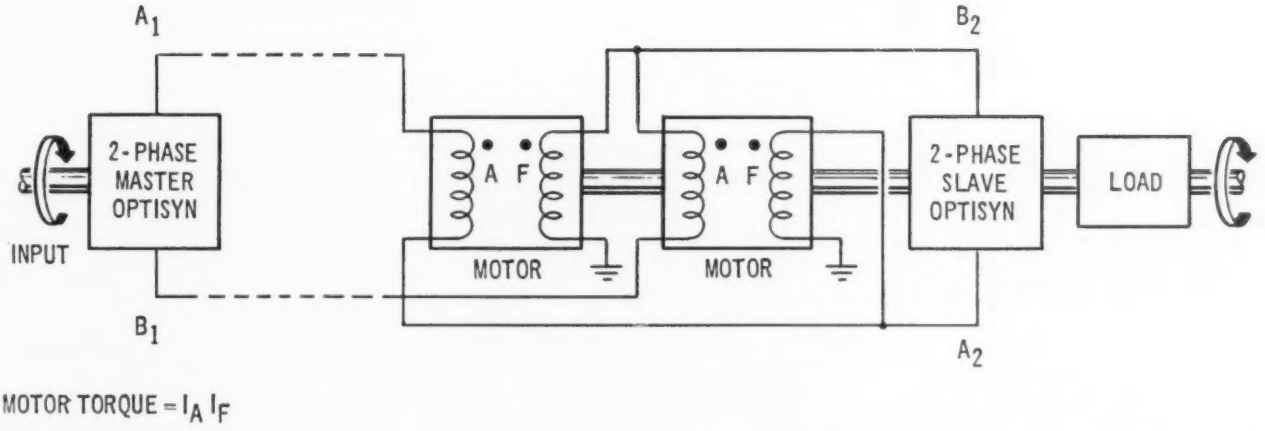

FIG 11—Optisyn system for accurate, remote shaft positioning. The slave Optisyn is rotated until its two outputs, A_2 and B_2, are equal to the master outputs, A_1 and B_1, respectively. The 2-phase outputs are 90° out of phase in each Optisyn. When $A_1=A_2$ and $B_1=B_2$, there is no error and hence no armature current flows through either motor. If A_1-A_2 has a magnitude and has the same polarity as B_2, an arbitrarily positive torque will be applied to the slave shaft by the left motor in the Fig. Should these polarities be opposite, the torque will then be negative. In both cases, the torque is proportional to the difference error A_1-A_2 and to the value of B_2. As B_2 approaches zero, the motor torque will become ineffective since its field will go in the same proportion toward zero. As this occurs, however, A_2 will be proportionately increasing in magnitude and building up in the field of the right motor. The torque correction of this second motor operates such that a negative correction torque is applied if B_1-B_2 has the same polarity as A_2. Otherwise, the torque is positive. The net torque is found to be proportional to the quantity

$$(A_1-A_2)B_2-(B_1-B_2)A_2$$

It can be shown that this net torque varies in direct proportion to the angular error. A breadboard prototype of this system was set up and tested. It was found to repeat shaft position to better than 1/30,000 of a revolution for an Optisyn having an n of 512. (The motors described have been separate, single-field, single-armature d-c motors. However, by using multi-pole, multi-brush motors, a single motor may be used in the transmission system. Also, a-c operation is generally applicable.

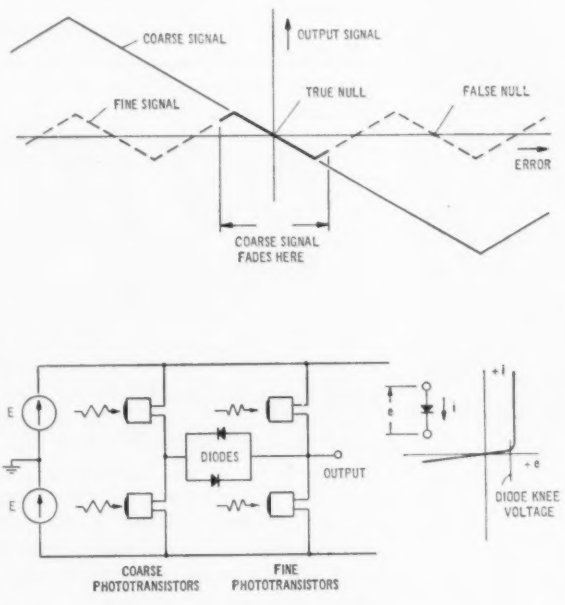

FIG 12—Waveforms and transistor interconnections for fine-coarse Optisyn control to reduce ambiguity in angular position. The fine-coarse transistor outputs can be paralleled as shown. A diode isolation circuit serves to cut out the coarse signal near the null position; but the coarse signal overrides the fine signal when appreciable displacement from null occurs.

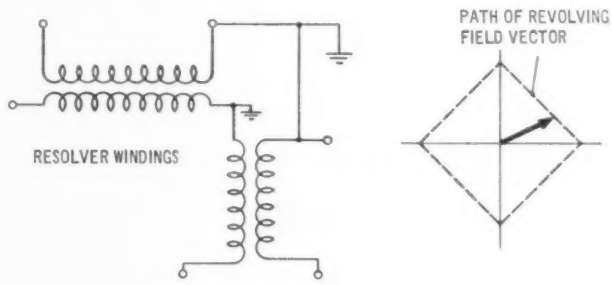

FIG 13— Resolver winding schematic and rotation of 2-phase magnetic vector.

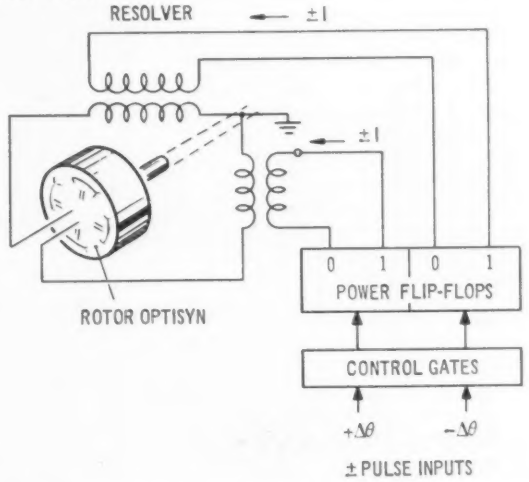

FIG 14—Optisyn-resolver for digital shaft power positioning.

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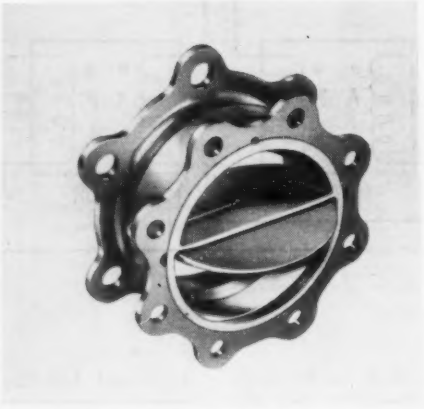
VALVES



Pneumatic Check Valve

Check valve, designed to check rapidly reversing high temperature and high pressure air surges, has only six pieces and butterfly design. Ambient and internal termperatures range from −65°F to 900°F; operating pressures are up to 250 psi; and maximum internal leakage is 0.05 lb/min. Weight is less than 0.9 lb. Mounting flanges are variable to suit applications. Barber-Colman Co., Rockford, Illinois.

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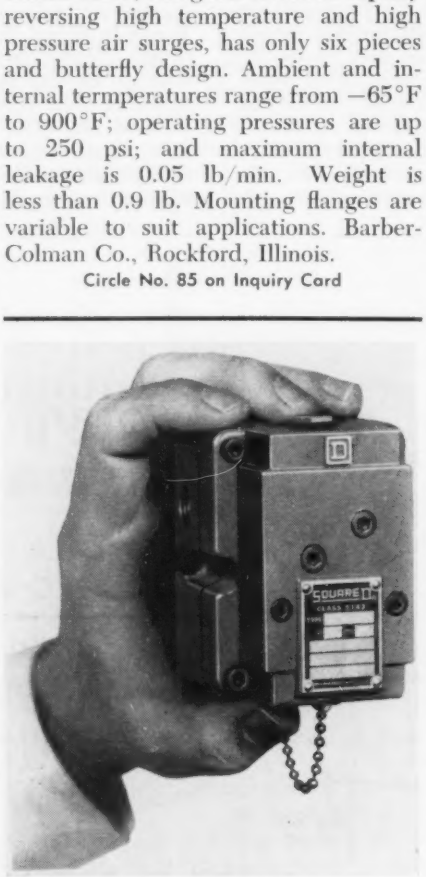

4-Way Rotary Air Valve

4-way air valve for use with spot welders, pneumatic tools and other industrial applications has rotary magnet which simplifies design and permits mounting in any position. Mounting at the cylinder, possible because of the valve's small size, eliminates need for long air lines between valve and cylinder. Balanced internal pressure increases service life. Valve has service life of more than 25,000,000 operations. Change of direction in air flow occurs in less than ½ cycle at 60-cycle frequency. Full ¼ inch porting is provided throughout. Air valve meets JIC specifications and is, also, made for optional manual operation. Square D Co., Milwaukee, Wisc.

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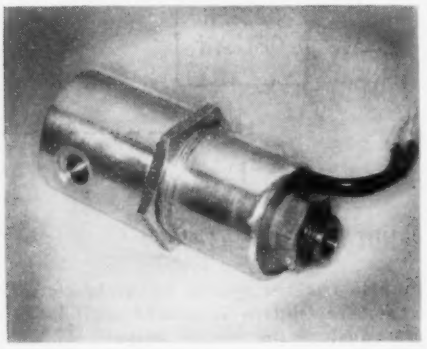

Solenoid Valve

2-way or 3-way, continuous duty, solenoid valve has low current drain and was operated 500,000 cycles without signs of leakage. It is qualified for 400 psi pneumatic, hydraulic and fuel services. Although it is a low cost, industrial type, it meets all applicable military specifications for aircraft and missile ground handling equipment. It was designed for a system to check pressure transducers where failure cannot be tolerated. Vinson Mfg. Co., Van Nuys, Calif.

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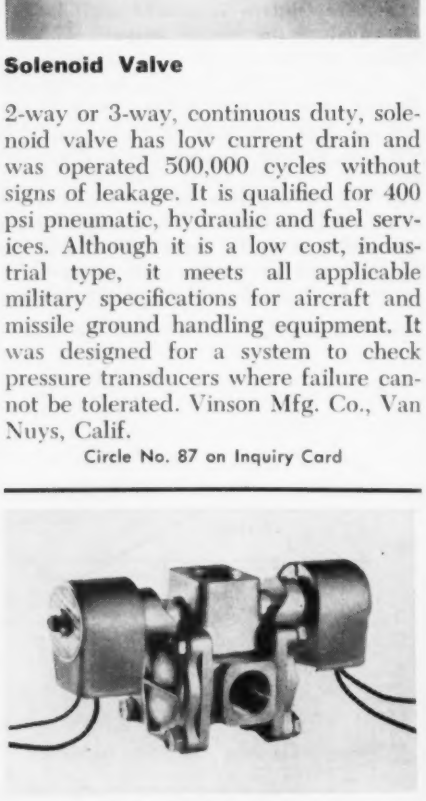

Dual Solenoid Inlet Valve

Dual solenoid inlet valve has a heavy forged brass body and bonnet, and Buna "N" diaphragms, eliminating corrosion problems. Two ¾ inch inlet connections and a common 1 inch outlet connection provide ample flow capacity. Normally closed operation (valve closes when solenoid is de-energized) is supplied. The dual solenoids may be energized together or separately as required. Pressure range is 5 to 125 psi. Valves operate on either A-C (10.5 watts) or D-C (10 watts), and are available at most standard voltages. Automatic Switch Co., Florham Park, New Jersey.

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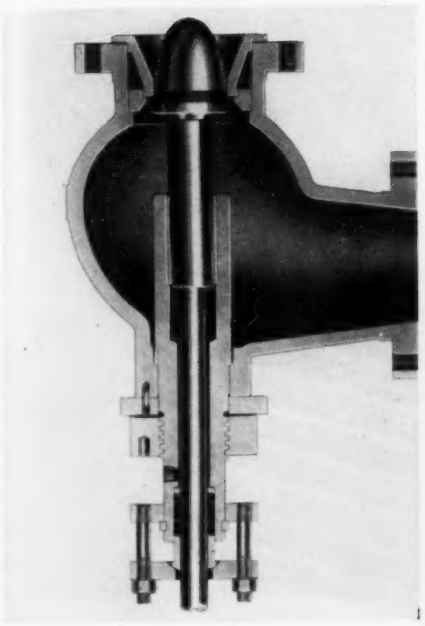

High Pressure Valves

Standard line of control valves have a patented, single-seated, angle design. Of extra heavy construction, the valve has a self-sealing bonnet, oversized stem and stem guide, and Venturi seat ring and parabolic plug, assuring tight shut-off. Sizes 1″ through 4″ carry ASA ratings to 2500 lbs.; sizes 6″ and 8″ to 1500 lbs.; sizes 10″, 12″ and 14″ to 300 lbs. In the smaller sizes the valves are equipped with a pneumatically positioned power actuator which provides sensitive valve throttling in response to standard 3-15 psi instrument signals. In larger sizes with high power requirements the valves have a completely pneumatic actuator capable of handling the high dynamic forces found in single-seated valves. Conoflow Corp., Philadelphia, Penn.

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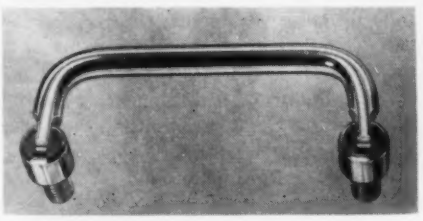

Folding Handle

Folding handle for panel and chassis, similar in size and shape to Cambion's folding handle, with the exception that the new handle folds against the panel in only one direction, is suitable for lifting purposes. Equipped with spring loaded detents which position the grip in both the upright and horizontal planes, the new Cambion folding handle is 4⅝ inches long and 1 13/16 inches deep. Cambridge Thermionic Corp., Cambridge, Mass.

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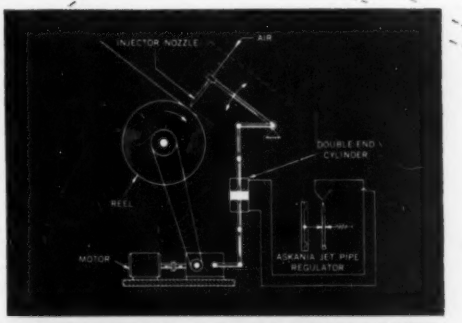
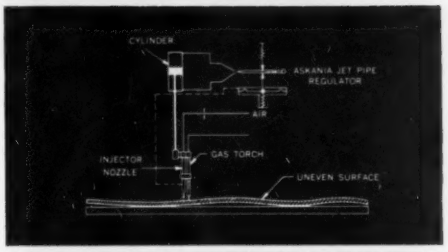
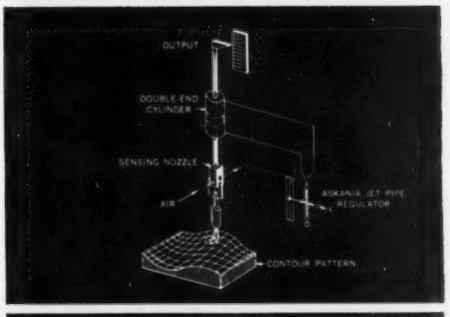
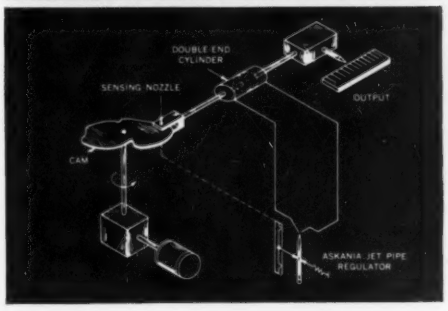
CIRCLE 14 ON INQUIRY CARD→

Powerful, accurate position control from a breath of air!









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3-PHASE STATIC INVERTER

Heat Dissipation Problems in Reliable Transistorized Design

Achievements in the field of static inverters are progressing so rapidly that by the time a production model of a new unit is marketed it is obsolete in comparison with prototypes or special purpose units. "Nevertheless," says Thomas Prouty Engineering Section Chief of Hallamore Electronics Company, "once a thoroughly reliable design of a static inverter has been achieved embodying solutions to the basic electrical, mechanical and thermal problems of such devices, keeping pace with or pushing the state of the art becomes relatively easy."

Hallamore engineers say they have solved these basic problems in a production model of a static inverter that transforms 28-volt d-c power to 3-phase 400-cycle sinusoidal power.

Principles of operation of the unit are simple. A stable, 3-phase, 400-cycle, transistorized oscillator, maintaining the correct frequency and phase relationship, drives power transistors in a push-pull switching circuit to produce high-power square waves. These square waves are then impressed across an efficient filter to produce a sinusoidal voltage output of low-distortion.

Adapted for either △ or Y connection, the unit produces a sinusoidal output that has less than 5 percent total harmonic distortion and that remains constant within ±2 percent from no load to full rated load. It is built to operate indefinitely under all service conditions of altitude, humidity and temperature and to withstand extreme shock and vibration. Internal components are sealed with an epoxy resin within a rugged cast aluminum chassis that requires only 399 cubic inches of space—1.6 cubic inches per output watt. An additional advantage of the unit is its extremely rapid starting time. Its output voltage reaches full value in something on the order of 100 microseconds. Starting times of this order are completely unheard of in rotary equipment. This characteristic is primarily of interest in applications of the unit as a stand-by device in conjunction with an automatic changeover circuit.

"Design objective of the inverter," Mr. Prouty said, "was to provide a device that would convert d-c power to a-c power at high efficiency and without the use of any moving parts. Elimination of moving parts was not an objective in itself, except that it seemed to be required from a sales standpoint." Its purpose was to obtain a vast improvement in reliability. "We were aiming," he said, "for the high altitude aircraft and missile markets. We felt that our experience in the field of transistor and magnetic circuitry put us in position to develop a suitable product using transistors as the active elements."

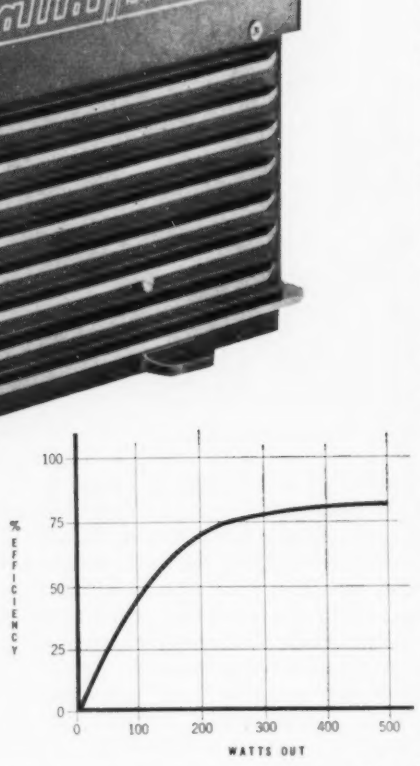
"It should be explained here," he said, "that static devices as such are not new in the industry; actually vacuum tube and thyratron inverters are static devices." However, use of vacuum tubes of any sort did not offer a significant improvement in reliability. It was necessary to use solid state static devices exclusively to achieve the objectives.

DESIGN PROBLEMS

Hallamore engineers had to develop new techniques to guarantee the reliability of the transistor in this application. Experience indicated that although a number of static inverter designs were perfectly satisfactory in a laboratory, they did not possess the inherent reliability required for missile and high speed aircraft environments. They found that the reliability objective entailed a multitude of minor problems.

"Looking back over the project," Mr. Prouty said, "it appears that every problem we approached was difficult, not because of inherent difficulty, but because of the multitude of new ideas involved simultaneously."

Powerized transistors capable of handling the power levels required were new. Transistor manufacturers had little experience in using transistors to switch powers on the order of 250 watts.



The basic circuitry itself had to be considerably different from that of any previous inverters, since the nature of the transistor imposes limitations precluding the use of conventional circuitry. Class B circuits, for instance, which have been popular in vacuum tube units and have been employed to some extent in transistorized units, don't possess sufficiently high theoretical efficiencies. Futhermore, the power losses in a Class B circuit appear at the collector of the transistor thereby placing the heat dissipation at the worst possible location.

In the switching mode, of course, most of the power dissipation can be moved over in the output transformer. "It was necessary to employ switching type circuits throughout," said Mr. Prouty, "to achieve sufficiently high efficiency."

Since a sinusoidal output was required, use of the switching mode made it necessary to add filters to remove the harmonics present in the square waveform. "The design of a filter that would operate satisfactorily into a very low impedance variable load with a variable reactance required an entirely new concept," Mr. Prouty said. New parameters, such as regulation, became

extremely important. Since the active switching elements are transistors, which are both current and voltage sensitive, it became very important that the filter input impedance be as nearly resistive as possible for all load conditions.

"The most difficult mechanical problem," Mr. Prouty said, "was that of devising a suitable internal structure for the inverter. The heat problem is extremely serious in transistorized equipment handling large amounts of power. It was necessary to locate the transistors so that they had the major share of the radiating surface of the case available for heat transfer. Such components as transformers, reactors, etc. which could be designed to operate at high temperatures, could be located in less favorable positions. "In the end," Mr. Prouty said, "this involved the use of insulating materials and special structures within the inverter to provide satisfactory heat flow. Handling the requirements of the mechanical structure and of the electronic components simultaneously, was extremely difficult during the design phase." As the area for heat transfer varied, so would the design of a transformer, since its operating temperature would then vary. "Since weight and size had to be minimum," he said, "the designs had to be optimized at all points." Extremely close cooperation between the electronics engineers and electro-mechanical engineers was required.

"In the course of approximately eight months of development on the inverter," Prouty said, "we tried many approaches that were unsatisfactory. These experiences could be condensed as a summary of what to do and what not to do. The primary rule is to keep the transistor cool at all costs." It has a maximum junction temperature of approximately 90°C. This derates about 1°C for every watt of power dissipated in the junction. Once the power dissipation is known, the maximum temperature at the junction can be calculated.

In the course of development Hallamore constructed no less than 5 complete prototype inverters in an attempt to determine the optimum combination of electrical and mechanical design. In the earlier models the main problem was that the transistor was not provided with sufficient area for heat transfer. As a result its temperature became excessive after short periods of operation in high ambients. Hallamore engineers are revising the internal structure again. This time, however, emphasis is being placed on cost and producibility. Although the present model solves the basic electrical, mechanical and thermal problems, it is unfortunately fairly hard to produce.

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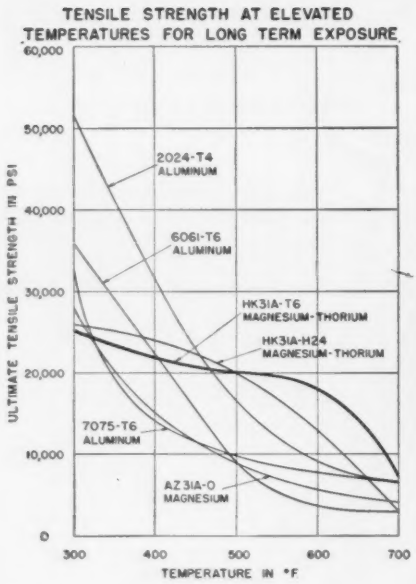

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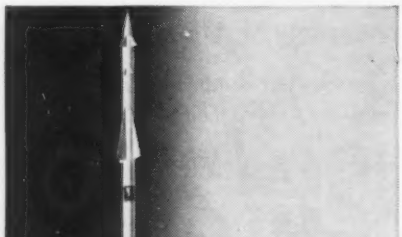

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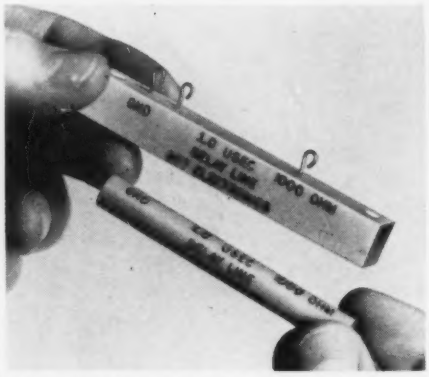

Subminiature Delay Lines

Series of delay lines, molded in epoxy resin, which are ultra-compact in size and meet the requirements of MIL-C-15305A, Grade 1, Class B, are supplied in square and tubular configurations for mechanical versatility in printed circuit applications or stacking on common mounting screws. Units can be stacked in series to give higher delays or tap-off points used to give lower delays. Impedance range from 500 to 2000 ohms, and delays up to 1 microsecond. Operating temperatures range from −55°C to +125°C. Maximum rise time for the longest delay is only 0.15 microsecond. Square unit measures ½" x ½" x 3½" long; tubular unit measures ⅜" O. D. x 2-15/16" long. NYT Electronics, Inc., Burbank, Calif.

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Precision Coaxial Attenuators

Precision coaxial attenuators, offering stability and ruggedness carry permanently marked, accurate calibrations at four frequencies. Models are available for 1,000 to 11,000 mc at 3, 6 and 10 db attenuation. 20 db models are available for 2,000 to 11,000 mc. All have impedance of 50 ohms. Calibration accuracy is ±0.2 db for 20 db models; ±0.1 db for the rest. Narda Microwave Corp., Mineola, N.Y.

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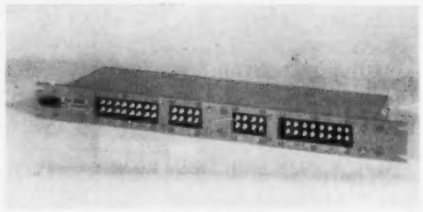

Balanced Audio Delay Lines

Series of balanced audio delay lines with various delay times up to 8 milliseconds—longer delays obtainable by cascading units—are precision calibrated and designed to introduce a constant delay over the useful audio frequency range of a standard telephone transmission cable. Synthesis from entirely passive elements provides increased reliability and economy. Electrical configuration of the balanced lump-constant type, which provides symmetrical dual input, and mechanical design conform to telephone specifications. All units fit standard telephone delay racks. Epsco Components, Boston, Mass.

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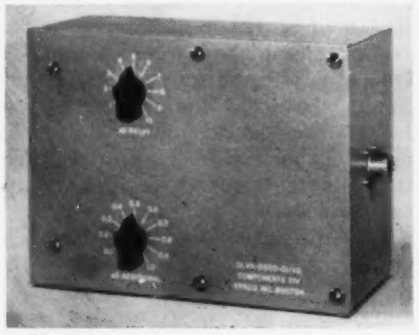

Decade Delay Line

Lumped-constant decade delay line features high impedance output. The following inputs are available: 500 ohms, 1,000 ohms, 2,000 ohms. Units are provided with coaxial input and output connectors and are variable from 0 to 11 microseconds in increments of 0.1 microsecond with rise times of 0.25 microsecond. Epsco Components, Boston, Mass.

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WORTH FILING

Tube Guide

20-page guide for Reliatron tubes including high vacuum amplifiers, ignitrons, thermostats, thyratrons, cold cathode gas relay tubes, gas and mercury vapor rectifiers, high vacuum rectifiers, camera tubes, phototubes, radiation detection tubes, and microwave devices. Guide also contains interchangeability chart.

Source: Westinghouse Electric Corp.
Electronic Tube Division
Elmira, New York

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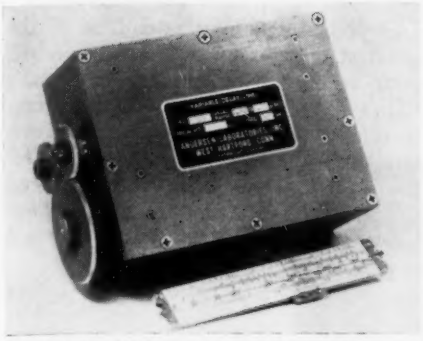

Variable Ultrasonic Delay Line

Variable ultrasonic delay line in which fused quartz is used as the delay medium has been designed for all operations in which control in setting the delay time is vital and band-width is required. The unit features a precision mechanical driving system. Andersen Laboratories, Inc. West Hartford, Conn.

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Transistor Tester

A direct reading, 3%, NPN or PNP transistor tester determines the small signal d-c gain (beta) for the grounded emitter configuration, the collector-to-base leakage current and the collector-to-emmitter leakage current. This new tester features transistor socket for plug-in testing, binding posts for in-circuit transistor testing, light-bulb indication of transistor shorts, an external-signal input jack for a-c measurements, and a variable Vcc. Western Instruments, Ridgecrest, California.

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WORTH FILING

Frequency Resolution

Latest 4-page copy of "PRD Reports," discusses the frequency resolution obtainable from a noise-jittered harmonic generation system. Specific case analyzed is that of a noiseless oscillator whose frequency is to be adjusted to zero beat with some harmonic of a frequency standard that is likewise immersed in noise.

Source: Polytechnic Research and Development Co., Inc. Brooklyn 1, N.Y.

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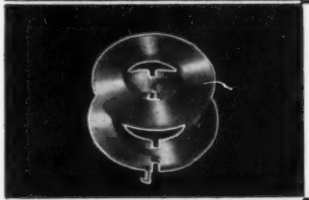

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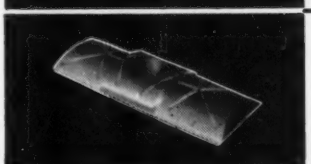

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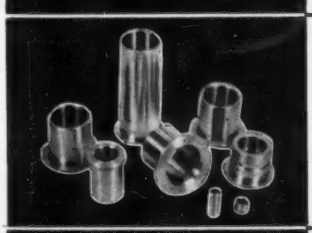

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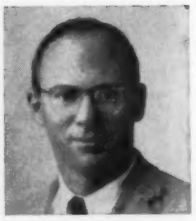
COMPONENTS DESIGN

STAFF COLUMNIST

Herbert F. Spirer

Assistant Chief Engineer
CGS Laboratories, Inc.
Stamford, Conn.



Strategy & Tactics for Reliable Designs

Last month this column talked about how the user frequently contributes to the unreliability of equipment. This month we are talking about the reverse side of the coin—how the designer by avoiding errors can increase reliability.

Obviously, given a specified amount of time and money we can buy only a limited amount of reliability. The trick is to buy the "mostest" for this specified amount. What are the approaches that can lead the equipment designer to equipment of higher reliability? My aim is not to give you specific instructions, such as "Use only XYZ bearings," or "Beware the oscillating cathode follower". Instead I want to give you some general design approaches that have proved to be helpful in achieving reliability. They are more matters of strategy and tactics; the procedure, the sequence and timing that the designer uses in seeking solutions to his problem.

● *Stamp out NIH (Not Invented Here). Good* ideas, not *your* ideas, pay off. NIH is not just "the other fellow's reactions to your ideas"—it is any negative reaction to someone else's ideas.

NIH can take many forms and use many devious methods. There is the designer who can never return to you a design embodying the simple solutions you suggested for investigation as part of your briefing. Some successful project engineers get simple designs only by deliberately avoiding the mention of the obvious so as not to rule it out of consideration. At the other end of the scale is the silver-tongued engineer who can give a hundred solidly based reasons that prove *this* equipment could not possibly work. If it had not been operational in large quantities for the last twenty years, you wouldn't realize how inapplicable his fine points are. And don't ignore someone else's ideas not explicitly based on logical reasons. Intuition you say? Intuition is unconscious logic, and I have yet to see a correct intuitional reaction that wasn't clearly and logically explainable.

● *Please the user, not other engineers.* Women who dress for other women, not for men, sometimes perpetrate minor atrocities. But engineers who "dress" their designs for other engineers may well create tragic situations. Although the user would never know the difference, a designer often replaces a satisfactory, well known circuit with an original but poorly understood one because he wouldn't want other engineers to see him use a "handbook" design! If the specs will be met and you know you will get adequate equipment life by using O1A tubes and Ultraudion circuits, then face the professional society music and use them. You may be red-faced, but you'll never be sorry.

● *Spend your resources only when and where you must.* Your only resources are time, money and manpower. You must spend these carefully and only where necessary. There are many difficult tasks in every design job. Unless you plan in advance sufficient time, funds and manpower for these tasks your completed equipment will not meet its specs, funds will be over-run and you will deliver late. One of the greatest dangers in any job is spending your resources on things that really didn't have to be done. Using a commercially available component in a system not only saves the time and manpower that would have been required to develop the component, but eliminates the risk of wasting time and manpower.

● *Don't fire until you see the whites of their eyes.* Resist the urge to start building hardware until you have finished the planning and designing and worked out most of your details on paper. The demand for hardware for a premature committment will be very forceful. It will come from many sources: from the customers, from supervisors, from company management, and most dangerous of all, from yourself. The minimum requirements that should be satisfied before construction are a written list of specifications on the object, giving range of inputs, outputs, environment and, where subject to later determination, a compromise set of specifications. These should be explicitly stated. Of course, your original plans will be changed a dozen times before the job is done, but by their very existence your are assured that the important factors will not be overlooked.

● *Know when to stop.* The function of the equipment designer is to build the equipment that meets the performance specifications within the limits of funds and time allowed. He should notify his management whenever in his judgment the time, money and performance specifications become incompatible—and be able to prove it.

A written description of how the object is to be tested is invaluable. Thus, prior to the excitement of debugging, there is a clear statement of "how good is good enough."

Without all this information on paper, it is possible to successfully build equipment; but the probability of such success is small.

The approaches to reliable design for equipment designers will be continued. Incidentally, I'd be happy to hear your comments.

Pressure Pickup

Stainless steel pressure pickup, ⅝ x 1⅜ inches, and weighing less than 35 grams and particularly suited to rocket and engine test stand applications, has been designed for an extremely wide range of gage and absolute pressure measurements. Operating without damage at temperatures from −300°F to +300°F, the pickup provides a nominal output of 40 mv. Pressure ranges from 7.5 to 5,000 psi gage or absolute are available in one model without configuration changes of any kind. Basically a flush-diaphragm instrument, the pickup may be adapted to closed line measurements. Vibration, acceleration and extreme temperatures have little effect on performance. Only one joint requires sealing, and leak and cabling problems are reduced. Integral part of the unit is a miniature connector, hermetically sealed to the case. Consolidated Electrodynamic Corp., Pasadena, California.

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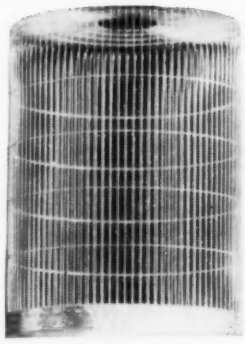

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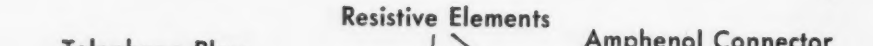


Fig 1—Cross sectional view of coaxial pulse current viewing resistor. An ungrounded lead passes through the center of the resistor assembly. The inductance within the probe is minimized by the physical arrangement of two cylindrical resistive elements of nearly equal value around the center lead. The two resistive elements are effectively connected in parallel and the current flow through the elements is such that the magnetic field across the output resistor is cancelled.

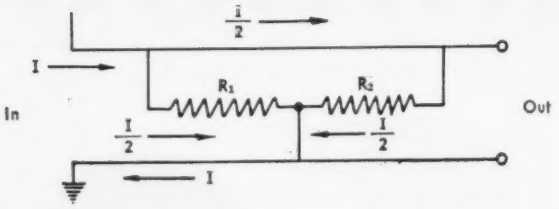


Fig 2—Schematic of coaxial pulse current viewing resistor. Note that in the left hand half of the current pulse viewing probe, a current of I/2 flows in the center conductor and the resistor R_1. In the resistor R_2, a current I/2 flows in direction opposite to the current in the center conductor. Since the current in resistor R_2 is in a direction opposite to that in the center conductor, essentially complete cancellation of the magnetic field takes place across R_2 and the output voltage is developed across R_2. It is impossible to completely cancel the magnetic fields, but this technique greatly minimizes the inductive effect. Very little pulse distortion is viewed on a synchroscope when these probes are used to view the current-wave-forms in magnetron oscillators and pulse-generator switch tubes with rise times of from 0.5 μ sec. to 0.01 μ sec.

CURRENT PULSE VIEWING RESISTOR

A Device for Looking At Magnetron Pulses

Frequently engineers need to view the shape of a large current pulse, as in the case of a transmitting magnetron. The magnetron current must be converted into a voltage pulse for presentation on the cathode ray tube of an oscilloscope. Various techniques may be employed to accomplish this purpose. Resistance voltage dividers, capacitance dividers, and series resistance capacitance dividers may be used. All of these have inherent technical problems, which are difficult and expensive to overcome, and problems of component requirements and configuration arise. Resistors of sufficiently low value are not available in a geometry easily applicable and usually their relatively high inductance prohibits their use. Capacitors present special impedance and calibration problems.

EARLY PROBE WORK

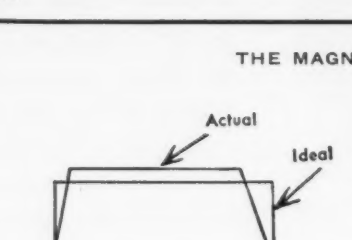
The development and design of a special resistor probe is another approach to current pulse viewing. Considerable work has been done on such a probe by the Radiation Laboratory of M.I.T. Subsequent to the work at M.I.T., the Bell Telephone Laboratories undertook the design and construction of this device based on the Radiation Laboratory's work. According to William Mulligan and Charles Wellard of International Resistor Company, the resulting pulse viewing resistor probe was superior to any available to that time but lacked the long term stability and high power handling capabilities that were desired. Most probes that were made had an inductance of approximately 0.01μh or higher probably due to mechanical variations, and as a result, lead to problems in actual use.

NEW PULSE PROBE

In 1955, under a supply contract from the Air Material center in Cambridge, Mass., IRC undertook the redesign of resistance probes of the Radiation Lab type. Some objectives were: improvement of inherent stability, power rating increase, wide resistance range coverage, decreased inherent inductance and, of considerable importance, reduction in price, since the initial pieces were quite expensive. Under the contract the objectives were met.

The special resistance probe resulting from this activity, according to Mr. Mulligan and Mr. Wellard, was constructed to minimize lead inductance and the inductance of the resistor itself. Since an ordinary resistor has so much inductance when the current pulse starts and momentarily presents a much higher impedance, special design precautions were neces-

THE MAGNETRON PROBLEM



Ideal and actual voltage pulses applied to magnetron oscillator. To function as a radar device, the magnetron oscillator must operate as a pulsed oscillator. The magnetron plate-cathode voltage must be switched on and off to produce the required pulses of RF energy, and the current must rise to its maximum value as rapidly as possible, remain steady for the duration of the pulse, and then fall to zero as rapidly as possible.

One of the reasons for a voltage pulse of rapid rise and fall is to avoid operation of the magnetron in a number of modes during the rise and fall of the voltage pulse.

The high voltage-short duration pulses needed for operation of the magnetron as a pulsed oscillator are usually generated in some form of a pulse-forming network. This network is an arrangement of series inductances and shunt capacitances in the form of a lumped-constant delay line, and will cause the actual pulse form to deviate from the ideal.

Another reason for the deviation is the magnetron itself. The magnetron is not a pure resistive load, and as the load impedance to the voltage pulse source varies, it will cause further distortion in the applied voltage pulse. The magnetron impedance drops in a non-uniform manner as the current rises to its maximum value.

sary. The desired results were accomplished by making the resistor probe a three-terminal device as shown and described in Figures 1 and 2.

OPERATIONAL FEATURES

The number of separate parts in the assembly has been kept to a minimum and design tolerances are such that parts of one probe are interchangeable with another. By employing the latest IRC techniques in film resistors, an excellent film resistor has been made with improved stability and load handling capabilities. Considerable work has been done on the development of pyrolytic high temperature films by IRC. Mr. Mulligan claims that results of this work have been employed to give the probe described its unusual stability. Resistance change with storage he says is less than 0.25% the first year with successive yearly changes decreasing. The probe inductance measured by the insertion method over a frequency range of 0.5 Mc. to 10.0 Mc. was less than 0.01 μh, and controllable. Mr. Wellard says that when these probes are used to check the current waveforms in magnetron oscillators and pulse-generator switch tubes with rise times of less than 0.5 μ sec., no distortion results.

Many pulse shapes are actually encountered in circuit work. Irregularities in the shape of the pulses complicate the interpretation of both amplitude and duration. The use of the pulse-viewing resistor with a good oscilloscopic viewing system permits flexibility for amplitude observations by substitution of resistors, and provides qualitative information regarding the shape of a pulse (Figure 3).

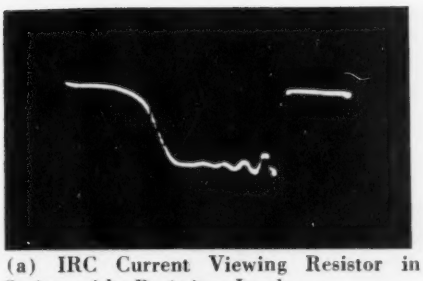
Pulse-viewing resistors are particularly applicable for viewing magnetron circuits, for measuring current of pulse generator switch tubes and as resistive elements in RC differentiators.

ENVIRONMENTAL PERFORMANCE

The physical size of the probe is six inches in overall length and ⅞ inches overall diameter. The main portion of the body (less phone plug) is 4¾ inches long. IRC's coaxial pulse-viewing resistors are rated at 15 watts continuously at a 40°C ambient. The surface temperature rise as measured at the center of the resistive film when carrying full load is 125°C. Resistance values range from 0.47 ohms to 100 ohms with the standard tolerance being ±20%. These resistors are individually marked to four significant digits, and the pair that comprise a probe assembly are matched to within a ratio of 60/40. They will handle pulse voltages up to 150 volts, and the current appears to be limited only to the average power dissipated, which is within the 15 watt rating.

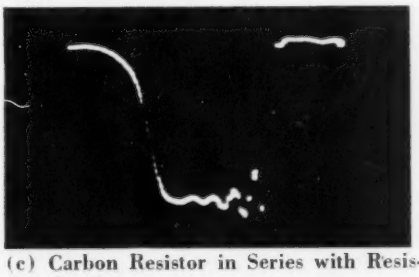
Another size, capable of dissipating 150 watts, is currently under development. These probes have been tested under many environmental conditions and have demonstrated their reliability, stability and their power handling capabilities. Humidity changes are less than 0.4% after 18 hours at 95°C, 100% R.H. These probes have been tested for 1000 hours in a 40°C ambient carrying rated load with very small changes in resistance. The probe end fits a standard phone jack type receptacle and the opposite end connects to a standard Amphenol microphone connector (Type 80M or equivalent).

Circle No. 56 on Inquiry Card

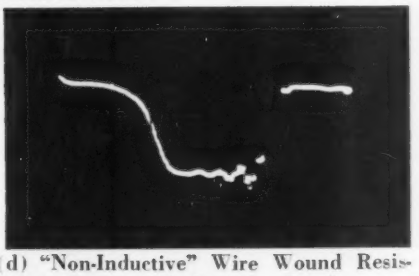


(a) IRC Current Viewing Resistor in Series with Resistive Load

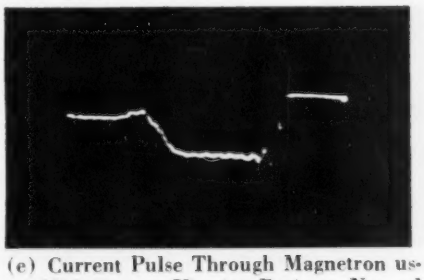
(b) Wire Wound Resistor in Series with Resistive Load.



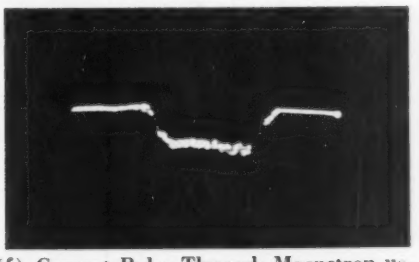
(c) Carbon Resistor in Series with Resistive Load.



(d) "Non-Inductive" Wire Wound Resisttor in Series with Resistive Load.



(e) Current Pulse Through Magnetron using IRC Current Viewing Resistor. Normal Functioning.



(f) Current Pulse Through Magnetron using IRC Current Viewing Resistor. PFN Functioning Improperly.

FIG 3—Relative quality of several types of resistors for oscilloscopic presentation of current pulses. (a) shows a current pulse using IRC's current viewing resistor. Curve shows a fast distinct rise time and a relatively flat pulse. The pulses obtained from a pulse-forming network are characterized by small oscillations. (b), (c), and (d) show the transients or "ringing" introduced by the inductance of conventional resistor. All examples of conventional resistors show a very indistinct rise time. The amplitude of these oscilloscopic presentations vary because the actual resistance of the resistors varied causing different display voltages. (e) and (f) show current pulses through a magnetron using IRC current viewing resistor. Both show good rise times and flat pulses. (f) shows a spike on the lead edge of the pulse because the pulse-forming network had no series inductance. It consisted only of a series of antiresonant sections and a series capacitor. This illustrates an improperly functioning network.

WORTH FILING

Electron Tube Shields

28-page edition of "Heat Dissipating Electron Tube Shields and Their Relation to Tube Life and Equipment Reliability," with charts, graphs, photographs, and cutaway drawings.

Source: International Electronic Research Corporation
Burbank, California

For your copy: Circle No. 60 on Inquiry Card

WORTH FILING

Optics Plus

First issue of Optics Plus, a quarterly publication published by the Perkin-Elmer Corporation covers missile tracking cameras and alignment devices for inertial guidance systems.

Source: Perkin-Elmer Corp.
Norwalk, Conn.

For your copy: Circle No. 75 on Inquiry Card

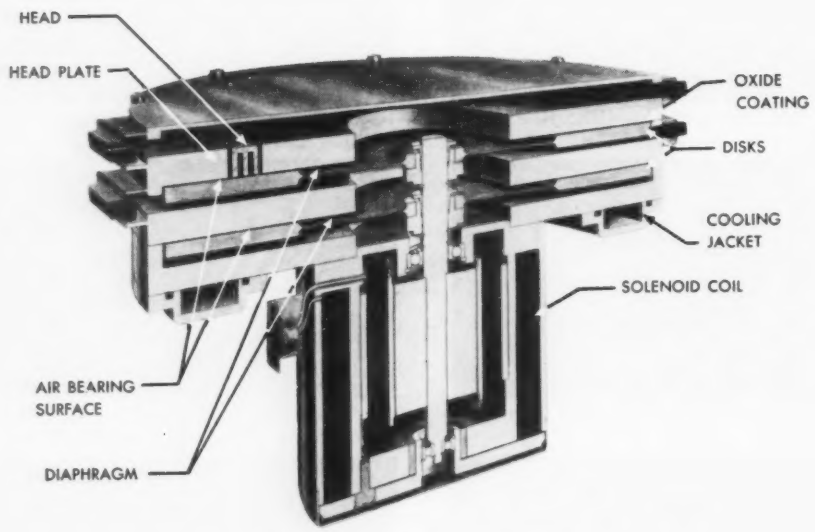


Fig. 1—Magnetic disk memory

COMPUTER MEMORY

Air Cushion Separates Disk from Recording Heads

Unlike most rotating magnetic memories—which are drum-shaped—a new magnetic memory unit for digital data employs a disk, because a flat surface requires forming only to shape, whereas a cylinder requires forming in both shape and dimension.

The new device is a time-sequenced, recirculating, precessing and storing memory, utilizing a magnetic-oxide coated, soft ferromagnetic disk. The disk revolves below a headplate containing fixed recording and reproducing heads of the open gap variety. Design objectives and construction details of the unit were described in a paper delivered at WESCON by W. A. Farrand, Computer Specialist at Autonetics, a Division of North American Aviation, Inc.

Units utilizing 32-bit loops with densities of 180 cells per inch have been operated with magnetic crosstalk of less than 2 per cent, readout modulation of less than 5 percent, and a base distortion of less than 5 percent. Write currents range from 4 to 20 ma. One of the units, containing 85,000 cells on 40 tracks, is 8-¾ inches in diameter and 6 inches high.

Recording is done on the flat surface of the disk, with the head-to-disk gap set by an autolubricated air bearing engaged and disengaged by a solenoid (Fig. 1). This bearing should not be confused with the usual air bearing, because air is not pumped into the gap. The functioning of this bearing involves a boundary layer property, and the forces developed are actually opposite in sense to those indicated by a simple application of aerodynamic principles. The force of separation is found to be a function of the viscous shear of the medium in the gap.

The disk is attached to the shaft by means of a very thin diaphragm (Fig. 1), which is designed to provide extremely stiff coupling between the disk and the shaft about the rotational axis, and very loose coupling in other directions. This loose compliance—in the order of pounds per thousandths of an inch—is utilized in the design for several purposes.

First, the spring (diaphragm) sets the preload on the disk. Next, if there is any misalinement of the headplate with respect to the shaft axis, this diaphragm flexes so as to maintain the disk parallel to the headplate. The diaphragm also flexes so that the force of the air bearing can offset exterior forces operating orthogonal to the surface of the bearing.

Because there is no support force at low speeds, the surfaces must be separated to prevent scoring the bearing surfaces. This is done by means of a solenoid actuator (Fig. 1). The solenoid's travel is the separation distance from disk to air bearing, and the additional distance necessary to cock the diaphragm to the preload force. To insure that the action of the solenoid does not enter into the dynamic problem of head-to-disk spacing, the solenoid produces a force when closed greater than the force which will react against it through the shaft. This can be accomplished simply, as the force across the solenoid for fine gaps is inversely proportional to the cube of the gap.

The heads are of the open, rather than of the ring variety; therefore, they use orthogonal rather than transverse recording (through rather than along the surface). This type of recording requires that the backing to the retentive oxide coating be a soft ferromagnetic material. Because the open configuration is far more adaptable to full shielding, open heads can be better shielded against magnetic crosstalk.

The diaphragm coupler, which maintains the disk irrotationally fixed to the shaft, allows stacking of as many disks on a shaft as are needed, provided that the motor torque to drive them and the solenoid force to lift them are available.

The unit is liquid-cooled; heat flows from the sensitive area (headplate) into the cooling jacket (sink), and from the heat source (motor-solenoid area) into the sink, but never from the motor or solenoid to the headplate. Since the first design requirement was for simplicity—and reliability—of design, only two radial bearings are used for the entire structure. Only a minimum of care and accuracy is required in the manufacture and assembly of machined parts. The two surfaces making up the air bearing require accurate machining only with respect to the reference plane of the air gap,

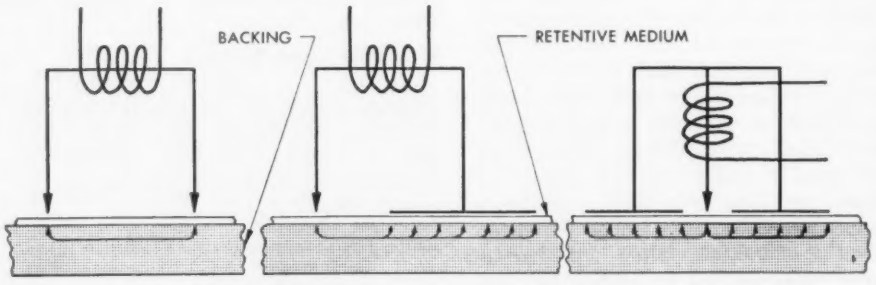


Fig. 2—Schematic of typical open heads used in magnetic recording

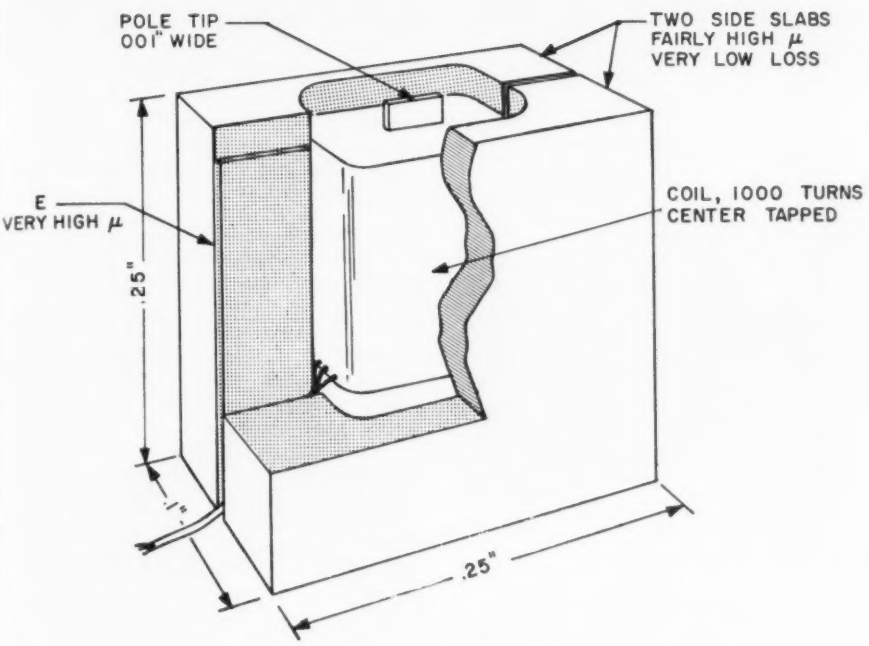


Fig. 3—Fully shielded open magnetic head

which is self-alining. Accuracies of the air bearing shapes are measured in microinches, but this is a shape tolerance, not a dimensional tolerance.

A few open heads are schematically shown in Fig. 2. At the left is a head that writes through the recording medium onto two tracks. This head is difficult to utilize because it requires alinement of the read and write heads on two separate tracks. Moreover, it requires that the land (the portion of the recording medium left blank between the tracks to minimize crosstalk) be doubled.

The second portion of Fig. 2 depicts an open head in which the heel area is very much larger than the toe area; therefore, saturation flux density can exist in the toe gap with very low flux density in the heel gap. Heads of this type, with the heel area covering only the track, have been tried, but cannot be made to operate for certain patterns of stored data (long-magnet effect). Because of this and other disadvantages, little use is made of this method of magnetic recording on either drums or disks.

The configuration shown at the extreme right appears to be most useful. It uses the same gap distance for heel and toe, but wraps the heel completely around the toe. This means that in writing, for example, the toe cannot illuminate any portion of the disk unless the return path goes directly to the heel. There is essentially no fringing flux from this configuration. With these heads the crosstalk has been reduced to less than 2 percent, even when the read and write heads are absolutely adjacent.

Crosstalk is measured as a percentage of full-read output, with full-write current being utilized in the adjacent head. Since the heads are very thin (0.1-in. thick), crosstalk data are taken at 0.1-in. spacing, far narrower than is normally necessary.

Physically, the heads are constructed as shown in Fig. 3. The coil is a simple layer-wound coil placed on the center leg of a high permeability metal E which is very thin. Around this are placed two fairly high-permeability, low-loss slabs of material which form the shielding and the heel pole faces. These very high permeability E's are not long enough on their outside legs to be a part of the heel pole face; thus, the heel flux is not concentrated in their area but is distributed over the entire heel area.

In the NRZ system of recording, the most perfect flux pattern that can be written is a square wave with slightly rounded corners (because this is a distributed parameter system). For this reason, squared demarcation lines are obtainable. A perfect derivative read head would thus produce a very sharp impulse voltage waveform at rise and fall of the flux. The best that one might actually achieve would be a nearly triangular wave of read voltage shaped such that the peaks of all waves are at the same amplitude, both positive and negative, with the base of the wave absolutely flat. This would mean that the dynamic characteristics of the read heads were critically damped, and that the write heads had very little capacitance; if the write heads were highly capacitive, their flux would build up exponentially rather than linearly.

It can be seen in Fig. 4 that, where a triangular output voltage pulse of width "d" results from a flux reversal at low density, then two flux reversals during the interval "d" represent the maximum pulse density which can be utilized without resorting to amplitude discrimination in the output. Such a condition corresponds to an alternate 1, 0 pattern in which the width of the output pulses is decreased by a factor of two as a result of increased pulse density, while a reduction in output amplitude is just being encountered.

In Fig. 4, it is seen that the coincidence of a sampling pulse with a read head output voltage above the dotted baseline is required to generate either a "set one" or "set zero" input to an associated memory flip-flop. The two output signals indicated are obtained by use of a center-tapped transformer at the output of the read head voltage amplifier.

Variations from this perfect waveform can be accounted for by a consideration of peak modulation from disk or drum runout, from the possible lack of homogeneity in the magnetic character of the retentive medium, and

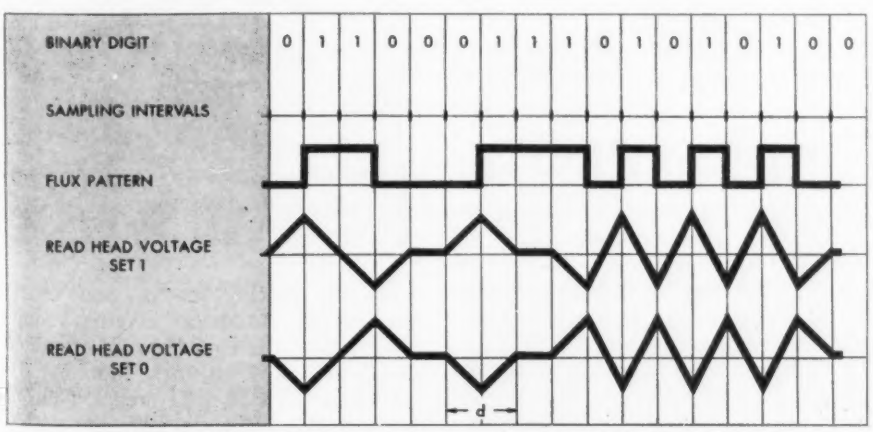


Fig. 4—Flux and voltage output waveforms for NRZ recording

from noise pickup. Base modulation arises from electrical head circuit oscillation and its associated damping, from noise pickup, and from inhomogeneity in the magnetic characteristics of the retentive medium. Also, one might consider the specific shape of the read pulse.

In most cases, however, it is sufficient to assume that all peak modulation is noise, defined as not signal, and that all base modulation is noise, again defined as not signal. Magnetic memory systems have been built with short loops at pulse densities of 500 per inch. Typical output waveforms can be seen in Fig. 5. Many computers require, or could use, very short loops (a loop being defined as a recirculation register). These heads, with no modification, produce loops as short as 0.1 in. If the recordings were at 100 cells per inch, this would be a 10-cell loop. With modification in the read and write heads, effective head widths of 0.050 in. with very low crosstalk may possibly be obtained. This provides a 25-cell loop at 500 cells per inch, or a 5-cell loop at 100 cells per inch, offering memories of great versatility.

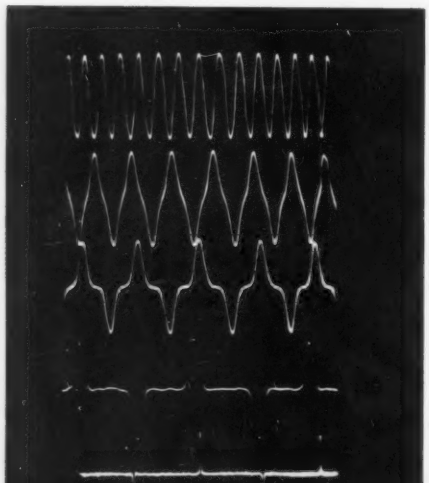


Fig. 5—Typical read waveforms

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WORTH FILING

Teflon-terminal Insertion Tool Directory

Handy Insertion Tool Directory in wall-chart form lists the many press-fit Teflon terminal types with their corresponding insertion tools, for quick and foolproof reference.

Source: Sealectro Corporation
Mamaroneck, New York

For your copy: Circle No. 71 on Inquiry Card

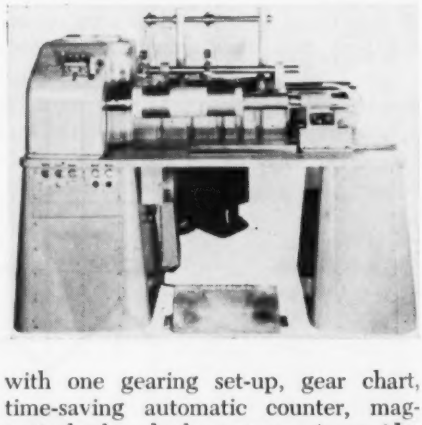
New Ultrasonic Drill

An ultrasonic drill with a power output of 100 watts drills intricate shapes into hard, brittle, unyielding materials such as glass, ceramics, quartz, precious stones; and other materials such as tungsten, carbide, silicon and germanium. The device includes 2 basic units; a drill assembly and an ultrasonic generator. The drill assembly consists of a piezo-electric transducer coupled to a tool mount by a mechanical transformer, and a drill mount and automatic, adjustable feed mechanism. Operating on a frequency of 20 to 22 kc. the high efficiency of the transducer and impedance matching system provides high cutting speeds with a minimum of power. Superseding the 40 watt drill originally developed by Gulton, the Glennite U-602 has been found to be extremely useful in industrial work, particularly in the manufacture of electronic components such as crystal diodes and transistors. Gulton Industries Inc., Metuchen, New Jersey.

Circle No. 109 on Inquiry Card

Multiple Transformer and Bobbin Winder

Compact, heavy duty transformer winder for multiple winding transformer, field and bobbin coils up to 16 in O.D. and 10 in long accommodates #4 to 23 A.W.G. wire as well as flat, square and rectangular wire. Custom-built shunt wound reversible 3 h-p, d-c motor assures uniform torque at low speed range. Maximum winding speed is 300 rpm, winding range from 2.7 thru 40.0 turns per inch and maximum loading distance for multiple winding 40 inches. Machine has instantly adjustable winding width, instantly reversible wire guide carriage, special immediate stop feature in case of wire breakage and 6-months lubrication supply in winding head. It is furnished



with one gearing set-up, gear chart, time-saving automatic counter, magnetic brake, dual purpose wire guides and heavy duty tailstock. Machine dimensions: 72 x 36 x 51 inches. George Stevens Mfg., Chicago Illinois.

Circle No. 89 on Inquiry Card

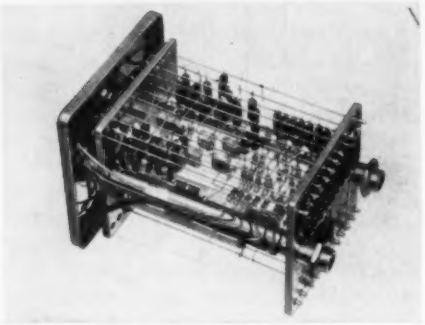
WORTH FILING

Variable Transformers

4-page data sheet describes 2 new series of small-frame powerstats that provide higher ratings with both constant-current or constant-impedence loads in single, two gang, and three-gang assemblies.

Source: The Superior Electric Co.
Bristol, Connecticut

For your copy: Circle No. 63 on Inquiry Card



"On-Off" Remote Control Equipment

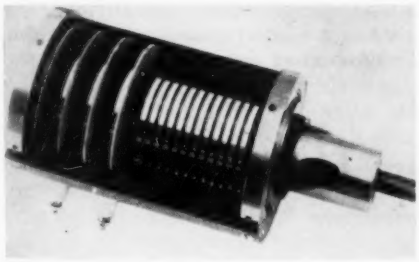
A system providing "on-off" remote supervisory control for motors, pumps, actuators, valves and switchgears, consists of a coder and decoder. Using either telephone lines, radio or microwave channels to transmit information, the system presents the control data at the central station for automatic, visual and aural monitoring. It transmits and receives individual code trains simultaneously and automatically monitors alarm conditions. The system is an all electronic device using transistors and diodes and has no moving parts. Constructed on a steel framework held in position by large through-bolts and housed in sealed steel case, the units are plug-in modules. Moore Associates, Inc., Redwood City, Calif.

Circle No. 100 on Inquiry Card

400 Cycle ServoMotor

Compact, velocity damped 400-cycle servo motor, BuORD size 11, provides low cost servo loop damping. In the unit, 1-51/64 inches long, damping is accomplished by the relative motion between a low inertia drag cup fixed to the rotor and an adjustable stationary permanent magnetic field. Conveniently located screw at rear of the motor adjusts the strength of the magnetic field, and can vary the no load speed of the motor from 5500 rpm down to 3900 rpm. Stall torque is 0.60 oz.-inches minimum. Special voltages and integral universal gearheads are available. Mechatrol, Westbury, L.I., N.Y.

Circle No. 101 on Inquiry Card



Centrifuge High Voltage Slip Ring

Centrifuge slip ring has three high voltage circuits capable of 10KV DC continuous and was tested at 20,000 volts hi-pot. Instrumentation circuits are unaffected by adjacent high voltage circuits. Precious metals in unit reduce noise. Dual brushes, riding on each ring and tuned to different resonant frequencies, assure uninterrupted circuits despite severe shock and vibration. All 15 slip rings and shielded wires are high pressure molded into one integral assembly for further protection against shock, vibration and humidity. The assembly, rated at 350°F continuous operation, ball-bearing mounted and sealed, has service life of 10 to 15 million revolutions at 6000 rpm. Slip Ring Co. of America, Los Angeles, Calif.

Circle No. 93 on Inquiry Card

ESCO standard components are assembled to meet your requirements.

A deviation from one of our standard switch assemblies will give you a *special switch* at a standard-switch cost.

Over 90% of our production is *special* in one way or another.

These standard switches can be modified to fit your application:

- *Type A* — up to 8 positions, 7 sections maximum, detent mechanism, rating 5 amp. 125 volts a-c/30 volts d-c.
- *Type AF* — up to 8 positions, 6 sections maximum, detent action, rating with resistive load 5 amp. at 28 volts d-c or 115 volts 400 cps, per MIL-S-6807.
- *Type P* — Multi-section, up to 4 positions, snap-action, rating 10 amp. 125 volts a-c, 5 amp. 125 volts d-c, 30, 60, 100, 200 amp. 500 volts a-c, or 250 volts d-c. Can be assembled to meet Specification MIL-S-15291.
- *Type JR* — up to 8 positions, 30 sections maximum, detent action, rating 10 amp. 125 volts a-c, 5 amp. 125 volts d-c.
- *Type JD-JS* — up to 8 positions, 5 sections maximum, detent action or snap action, rating 30 amp. 230 volts a-c.
- *Type HT* — up to 16 positions, 10 sections maximum, detent action, rating 5 amp. 125 volts a-c.
- *Geared-Pair Type HT* — up to 16 positions, 20 sections maximum, detent action, rating 5 amp. 125 volts a-c. A single knob controls two Type HT switches assembled with a gear mechanism.
- *Navy Switches* — to MIL-S-15291 and Bureau of Ships drawings 9000-S6202-73075, 73826, 73827, 73295, 74422, and others.

Write for data sheets on individual switches or complete new catalog on ESCO rotary multipole switches. Send us your requirements and we'll give you full specifications on the ESCO switch that meets *your* need.

ESCO *of* WEYMOUTH
ELECTRO SWITCH CORPORATION
Weymouth 88, Massachusetts

FOR MORE INFORMATION CIRCLE 19 ON INQUIRY CARD

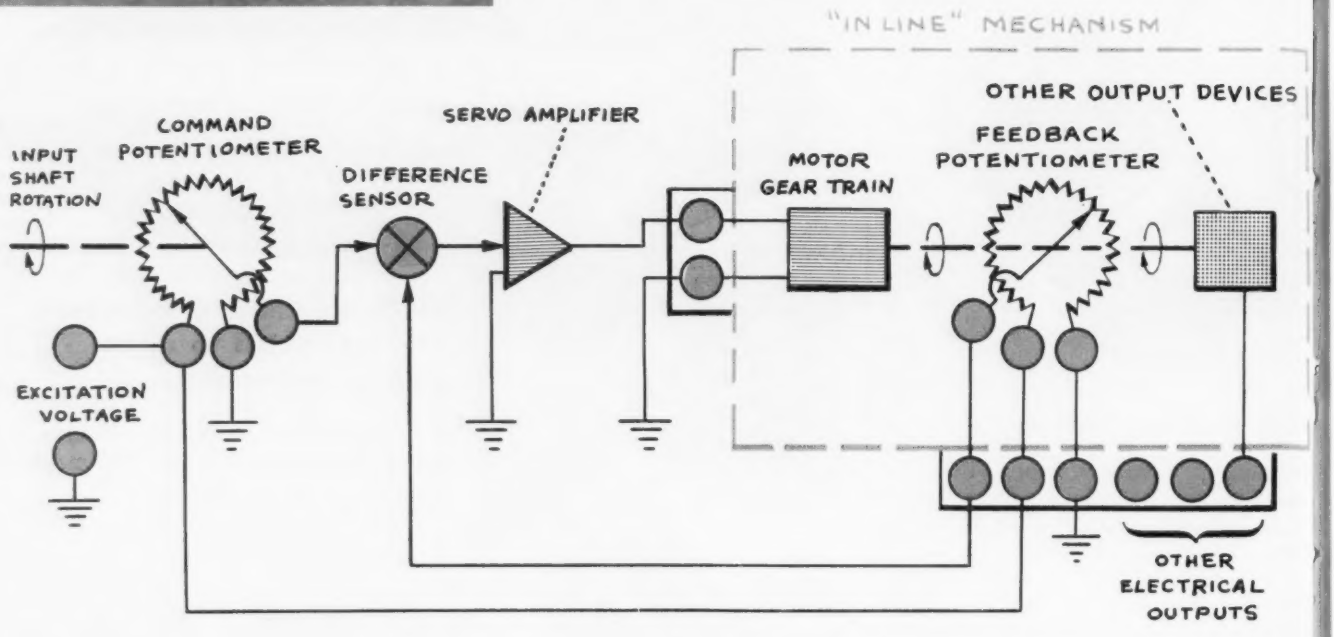


FIG 1—Typical position servo. A potentiometer, used as an input transducer, converts a shaft rotation into a proportional electrical output. This output is applied to a difference sensing device. The difference sensor also receives a voltage from a feedback potentiometer that is proportional to output shaft rotation. The sensor output, which is the difference between the input and feedback voltages, is applied to a servo amplifier and then to the motor. Connections are so arranged that the feedback voltage is made to approach the magnitude of the input voltage as a function of output shaft rotation. When these voltages are equal (ie., when their difference is zero) the system comes to rest. The system remains effectively in this null condition until a new input command is received. The motor, gear train, feedback potentiometer, and all other output devices are contained in a co-axial module as indicated by the dotted outline in the illustration.

In-Line Mechanisms

A New Approach to the Design of Sub-system Modules

Co-axial mounting of rotating components on a common shaft provides optimum use of space and weight in sub-system module design. This in-line concept combined with modular design techniques offers the systems designer almost unlimited freedom of selection in modular packaged sub-systems.

Electromechanical systems have become so complex in many cases that system designers today are inclined to think in terms of functional sub-systems. Since certain groups of components are frequently repeated, the designer uses these basic component combinations, with only slight modification, as the building blocks of his system. One example of such a combination is a servo motor driving a potentiometer in a servomechanism. Giving impetus to this trend, Spectrol Electronics Division of Carrier Corporation, San Gabriel, California, is combining many of these frequently repeated groups of components into sub-system modules.

Burton D. Swirsky, Supervisor of the Division's Electromechanical Design Group, cautions that hardware development must pace this sub-system design concept to make it effective. He points out that even in cases where the modular or building block approach is practiced at the design stage, the burden of component specification too often rests with the systems engineer. The package design for each functional sub-assembly is treated as an original creation although similar problems have been solved before.

In computer design, for example, a typical sub-assembly

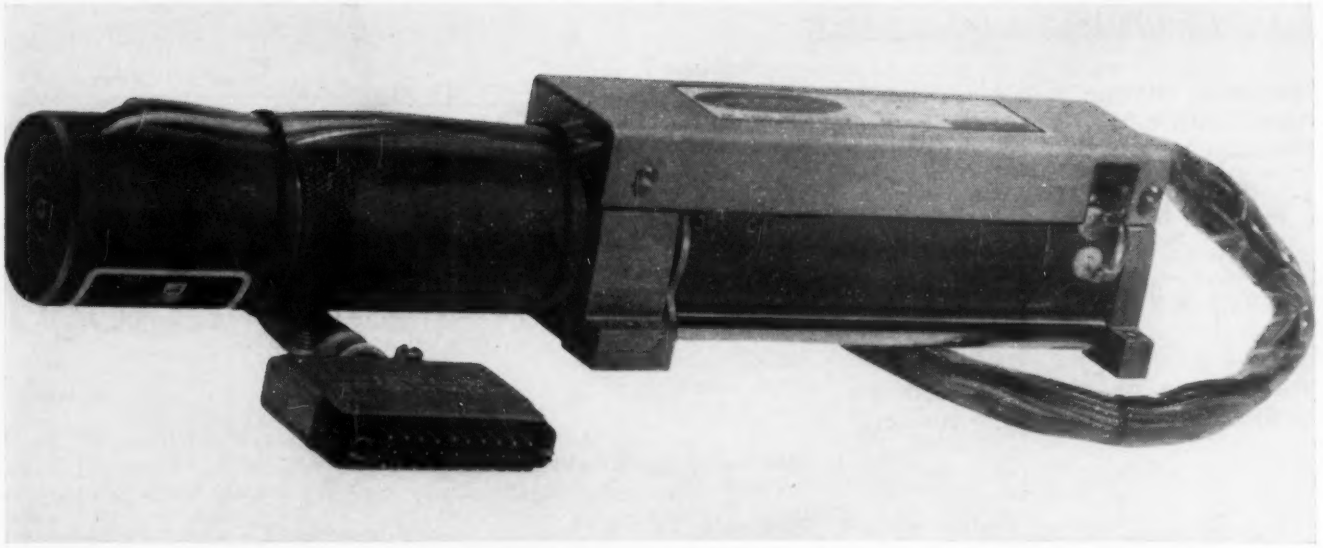


FIG 2—Typical sub-assembly of components assembled on a single stainless steel shaft. The servo motor has a no load speed of 6500 rpm and produces 0.6 inch-ounce of torque at stall. It is a BuOrd size 11, two-phase servo motor requiring 115 volt, 400 cycle excitation of the reference winding, and 40 volt, 400 cycle excitation of the control winding (compatible with transistorized servo-amplifier requirements). The size 11 gear train housing provides a speed reduction ratio of 1000:1. This ratio is achieved by a train of AGMA, precision class 2, spur gears having a maximum of 30 minutes of backlash measured at the output shaft. A slip clutch is provided within the gear head housing of the unit shown, in order to protect the potentiometers, which require a driving force of about one inch-ounce for operation. The clutch is designed to slip at 8 inch-ounces when the potentiometer is driven to its end position. Its mechanical stops are designed to withstand two inch-pounds, thus providing adequate overload protection. The potentiometers are standard Spectrol Model 700 units. Each potentiometer, ⅞ inch in diameter, has a linearity of 0.2 percent and a power rating of 1½ watts at 40 degrees Centigrade. Maximum resolution of the potentiometer gang is 0.1 percent. Mechanical stops of the potentiometers are placed close to the driven end, in order to avoid excessive torsional deflection when the potentiometer and switch terminals are approximately the same diameter as the standard servo motor. A package which is nearly cylindrical results. The whole assembly occupies approximately half the volume that the same components would occupy in a side-by-side mounting.

such as a servo multiplier may appear a number of times Yet, each case is treated as a new design problem because of relatively minor changes in configuration, such as gear ratio or potentiometer resistance. Mr. Swirsky says that this treatment of sub-assembly design, along with system analysis and design, places a heavy and unwarranted burden on the systems designer. If standard functional sub-assembly units can be used, the details associated with assembling a group of varied components into a system sub-assembly need not be the concern of the systems man. He can, instead, devote his time to the perfection of an optimum over-all system.

Spectrol's standardized electromechanical sub-assemblies comprise a variety of electrical and mechanical components mounted in-line and are faithful representations of the functional blocks which compose the basic elements of a servo system.

Using such modular standardized sub-assemblies, the system designer can take full advantage of the sub-system approach to his daily problems. He can call out a modular electromechanical sub-assembly as readily as he specifies single components. In this sense, the in-line modular units bring to electromechanical design much of the simplicity that similar assemblies, such as amplifiers and demodulators, have brought to electronic design.

Mr. Swirsky points out, however, that to be effective, modular electromechanical sub-assemblies must duplicate the transfer functions specified in the corresponding "blocks" shown on the system designer's diagram. Only in this way, he says, can the sub-system approach to system design be transferred to hardware design. The electromechanical assembly and the block must be considered as identical building block units. It is this concept that has provided the major elements of the modular in-line design philosophy.

A TYPICAL MODULE

Typically, a modular in-line sub-assembly consists of a transducer, whose purpose is the conversion of a mechanical motion to a specific electrical output; a motor as a driving mechanism; and gearing, clutches or other accessory equipment, necessitated by the requirements of the system. A common form of transducer is the potentiometer, and one of the simplest modular sub-systems is a servo motor driving a potentiometer, to produce a specified output function in accordance with certain input command signals.

Figure 1 is a diagram of a simple position servo which serves to illustrate the concept of modular electromechanical packaging.

In the past, the various components making up such a module were specified and purchased individually. The system designer's specifications relating to system dynamics had to be interpreted in terms familiar to the manufacturers of a multitude of components. In addition, efforts of the components and packaging engineers had to be coordinated by a responsible systems engineer.

The task of resolving these multiple problems is now removed from the domain of the systems designer and transferred instead to the designer of the electromechanical module. The various problems arising in diversified fields of system design make it more feasible for the sub-assembly specialist to design a packaged module directly from the system or sub-system block diagram specification than for each system expert to design his own electromechanical building blocks.

MODULE TESTING, MAINTENANCE, AND PURCHASING

Simplicity of design is the obvious advantage to the modular concept. But, as Mr. Swirsky points out, there are other

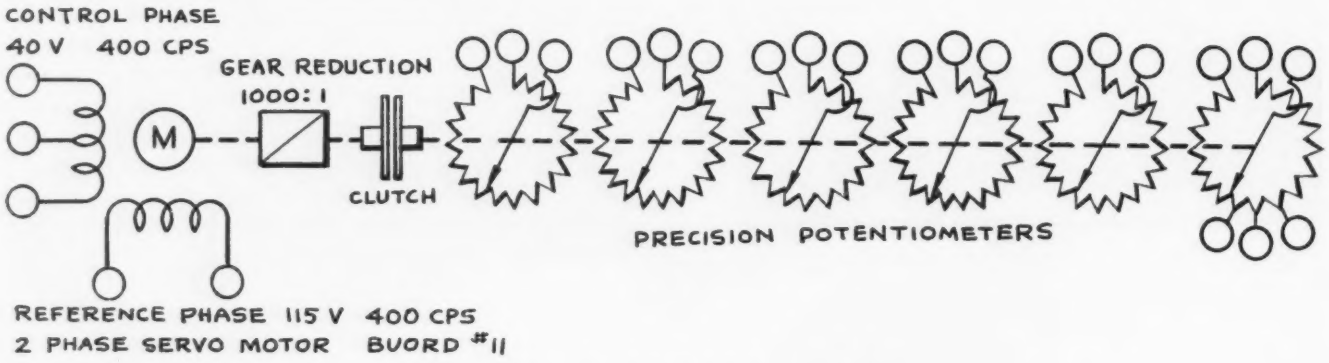


FIG 3—Schematic of typical in-line mechanism.

equally important advantages.

Testing and quality control, for example, are performed on assemblies rather than on individual components. This performance evaluation of a sub-assembly on a go-no-go basis is preferable to elaborate detailed testing of a group of miscellaneous components. Not only can one test specification delineate all the performances and functional tests the sub-assembly must meet, but also tolerance accumulation between components, having been considered in the initial sub-assembly design, does not influence the over-all test procedure. Receiving and inspection departments, too, can handle only one unit instead of several and perform only one test or group of tests. In addition, final inspection results of the supplier and receiving inspection tests of the customer can be more readily correlated when modular testing is employed. Consistency and repeatability of test results is a goal that is readily achieved.

Reduced numbers of parts necessary to be stocked plus smaller space required in which to stock them provide additional economies. Along with this is the reduced possibility of parts becoming lost or damaged in handling, since there are fewer parts.

Similar benefits accrue to the purchasing department since only one assembly is ordered instead of a variety of components. Less paper work means faster processing of orders and better delivery schedules. Problems of specification interpretation are reduced in scope since only one vendor is concerned.

An extremely significant advantage in the modules concept is design flexibility. The cost of tooling or of specially built components is a major consideration when prototype quantities are considered. When the detailed design of the modules is governed by considerations of interchangeability and standardization of the parts, tool costs are reduced, and design decisions can be made on the basis of accuracy and reliability. Standardization, therefore, is of prime importance in the development of sub-system modules.

Modular maintenance has long been an accepted military concept. Field servicing, for instance, can be carried out by the "remove and replace" technique which requires that the field technicians know only how to remove a module and replace it with a new one from stock. Delays encountered in the trouble shooting of many individual components are eliminated by this proven technique.

"IN-LINE" MECHANISMS

An in-line mechanism may be defined as a series of coaxially packaged components for which over-all performance and environmental characteristics are specified. A typical example of a simple in-line mechanism is illustrated in Fig. 2, where a size 11 servo motor, a 1,000 to 1 gear reduction unit, a slip clutch and six precision wire wound potentiometers are mounted on one shaft. The schematic of this in-line mechanism is shown in Fig. 3.

Assemblies designed with all components in-line, mounted on a common shaft provide fabricating techniques unmatched in reducing tolerance build-up within the mechanism. In addition, precision electrical components mounted on a common shaft provide an optimum in space and weight utilization, as well as an opportunity for increased accuracy.

Although the servo motor-gear train-clutch-potentiometer combination is most common, any component adaptable to rotary operation may be used in a modular in-line mechanism. Examples include magnetic dampers, electromagnetic brakes, spring return devices, dials, resolvers, induction potentiometers, synchros, tachometer-generators, and switches.

Modular in-line mechanisms require little more space than formerly needed for a single component in most cases. Figure 4 shows a diagram of a typical servo assembly composed of several rotary components, each with its own shaft. Figure 5 shows a diagram of an in-line mechanism designed to provide identical output functions. Savings in space and weight are readily apparent from a comparison of the two diagrams.

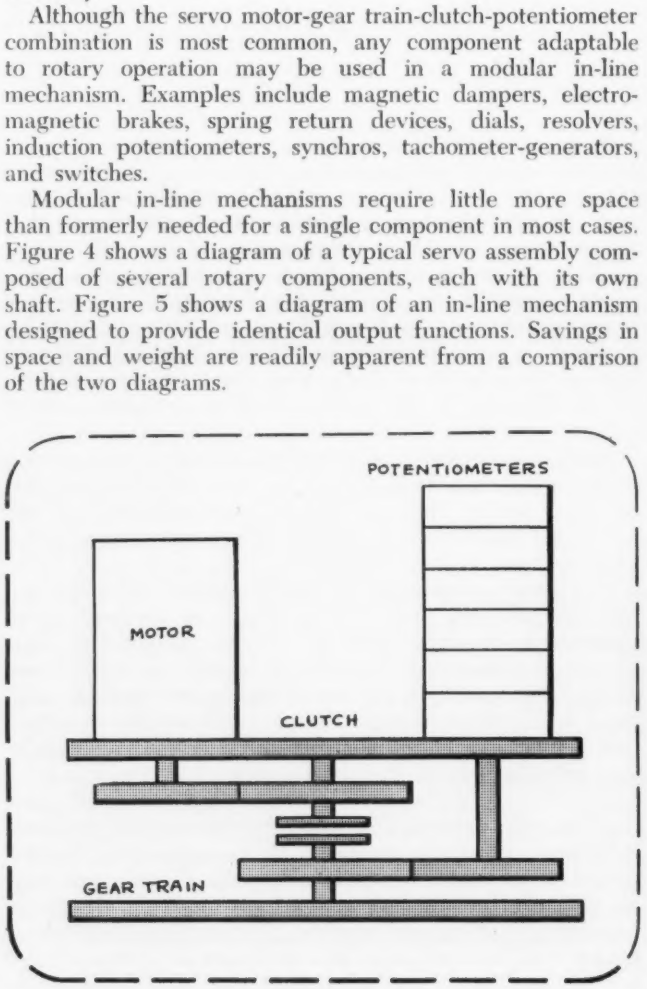


FIG 4—Typical panel mounted servo assembly.

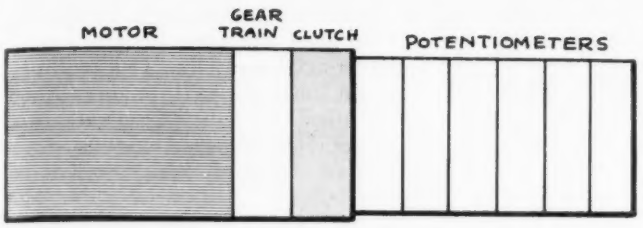


FIG 5—Same servo as in Fig. 4 when mounted in-line requires less than half the space.

COMPONENTS

Of all the small rotary components adaptable to instrument type sub-assemblies, probably the most widely used are potentiometers, because of their simplicity and versatility

Standard potentiometers usually contain one, three or ten turns. However, potentiometers with a range of any number of revolutions, including fractional, may be designed. The relative ease with which such potentiometers may be adapted to specialized applications provides maximum flexibility for in-line mechanisms. Instead of specifying a special gear head, for example, a desired function may be contained in the potentiometer itself. Since it is easier to change the design of a potentiometer than a gear head, and since fabrication of potentiometers is usually more quickly accomplished than the manufacture of custom gear trains, more rapid delivery and low over-all costs result when the potentiometer is made the variable design factor in an in-line mechanism. Of course, as previously mentioned, potentiometers alone cannot provide all the functions required by electromechanical systems.

Printed-circuit rotary switches readily lend themselves to use in in-line mechanisms; Figure 6 is a photograph of a typical switch. Switching functions are practically unlimited and many switches may be mounted on the same shaft. Spring return mechanisms in conjunction with an electromagnetic clutch may be used for positioning the switch to "off," or to any other specified position.

Gear reduction units designed to provide the desired velocities and accelerations of the output devices are supplied as integral parts of an in-line mechanism.

Miniature, two-phase servo motors, for either 60 or 400 cycle excitation are usually supplied. However, synchronous, induction, or d-c motors may be used.

Electrically actuated clutches or brakes are used to disconnect the output device from the driving element and to maintain constant rotational speed where necessary. Likewise, a variety of magnetic dampers may be installed if required by the dynamic characteristics of the system. Dials or indicators are available for visual indication of system performance, and tachometers, either a-c or d-c, are used to supply a voltage output proportional to the speed of the driving motor.

Resolvers that provide sinusoidal output voltages proportional to rotational position, synchro control transformers that give a null indication, and induction potentiometers that achieve a linear a-c output proportional to position are all easily adapted to in-line mechanisms. The basic scheme has only begun to be applied in a few of the myriad possible configurations that systems designers will no doubt come up with in the next few years.

MOUNTING METHODS

Conventional mounting methods are used to install in-line mechanisms. Servo mounts, bushing mounts, tapped hole mounting or flange mounting is provided in accordance with the design specifications. When the over-all length of the in-line mechanisms becomes too long to be readily installed on a single mount, mounting brackets may be added at both ends. Center of gravity mounts may be used when the shock and vibration requirements are very severe.

Mechanical stability and inherently higher natural frequencies associated with in-line mechanisms make their use far more desirable than side-by-side mounting of several components connected by elaborate gear trains. It is possible, if required, to mount several in-line mechanisms in a fixed geometrical relationship and interconnect them by bevel, helical, worm, or spur gearing. END

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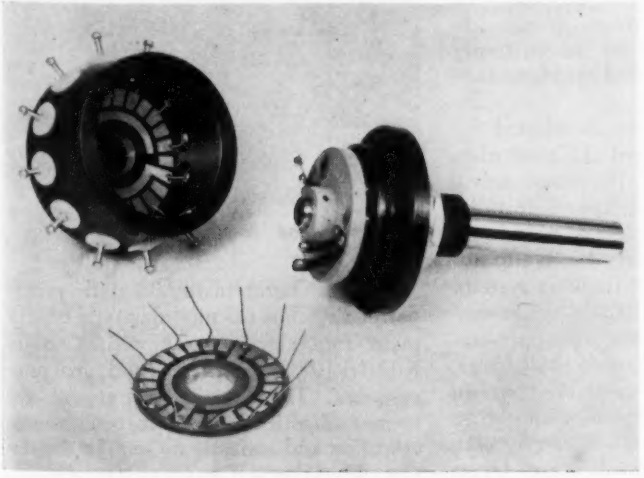

FIG 6—Disassembled printed circuit switch.

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Compact design of instruments and other precision mechanisms calls for critical evaluation of all components in terms of the space they require.
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SYSTEMS DESIGN

INSTALLATION HARDWARE FOR BLACK-BOXES

Multi-Function Chassis Latches Simplify Computer Design

The increasing complexity of electromechanical and electronic equipment has led to a marked need for easily interconnected standard "black boxes" that may be re-arranged as required to perform specialized system functions. Ease of servicing and rapid withdrawal and reinstallation to create varied and reliable system combinations are primary design criteria.

The "black box" design philosophy has resulted in the development of a wide assortment of basic standard packages, each thoroughly engineered for compactness, reliability, and versatility, as well as first-rate performance. The systems engineer can easily combine these packages as required to assemble a wide variety of special purpose electromechanical and electronic equipments. This technique is undoubtedly most marked in the analog computer field, where a relatively small group of basic units such as amplifiers or servo multipliers can be assembled to perform complex mathematical operations.

William Seiden, Chief Design Engineer at Dynalysis Development Laboratories, Los Angeles, California, believes that ease of interconnecting the separate packages is the key to successful use of the black box approach to system design, and that therefore installation hardware should receive a greater share of engineering attention. "There is a tendency," he says "to minimize this aspect of design, reserving action to the later phases of the development program. At that time the hardware problem may be resolved in an uninspired manner, using common standard commercial parts in conventional arrangements.

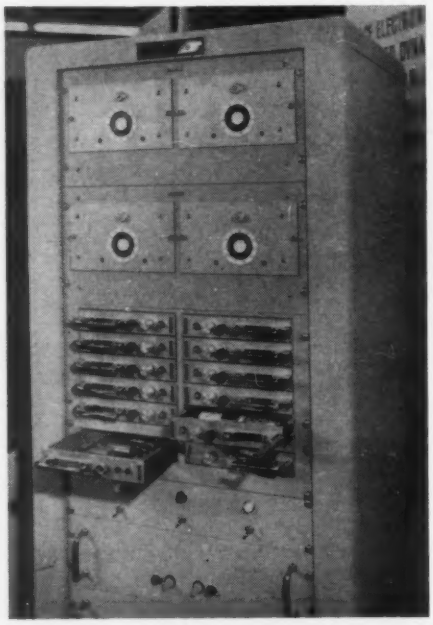

Fig 1—Coordinate Converter computer by Dynalysis Development Corporation employs twelve multiple-function Camloc chassis latches on rack-mounted d-c amplifier chassis.

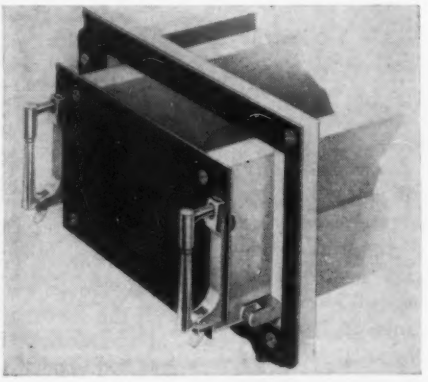

Fig 2—Close-up of latch-type fastener showing principal parts. When the lock is released and the handles are pulled down for withdrawal of the amplifier, the chassis is automatically disconnected and ejected. Conversely, locking the latch firmly pulls the chassis into place, making perfect, automatic reconnection. The latch works quickly, safely, and reliably, is vibration-proof, and requires no special tools. Although it readily supports a 400-lb horizontal load, it is easily manipulated. The latch provides a convenient sturdy carrying handle, especially important when a hot electronic chassis, which may include charged condensers, is pulled for emergency servicing.

"While at times this approach may yield a suitable finished product, it often overlooks the possibility of achieving striking design advantages through optimization of mechanical installation hardware. The ease of servicing and component utilization that may be achieved in an optimum design are frequently as significant in customer appeal as the detailed performance specifications."

An analog computer developed by Dynalysis Development Laboratories, Inc., shown in Fig. 1, illustrates a system with carefully designed installation hardware. This coordinate converter is a specialized d-c computer used as part of a target tracking system. Its operation is based upon an assembly of high-performance chopper-stabilized d-c amplifiers, servo multipliers, and servo resolvers. Suitable plug-in cans are used in the separate amplifiers to perform the functions of summation, integration, and multiplication by a constant.

In place of the more common fastening and locking techniques, the designers installed on each of the twelve function amplifiers (Fig. 1) a multiple-function chassis latch, manufactured by Camloc Fastener Corporation of Paramus, New Jersey. Figure 2 shows details of the latch and describes its functions.

"Notwithstanding the commonplace nature of most fastening problems," says Mr. Seiden, "adequate attention to fastener design can achieve gains in serviceability, flexibility, ease of handling, and consequently overall economy. Although the variety of standard fastening devices is very great, special purpose variations are generally available for the really unusual job."

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WORTH FILING

Temperature Controls

8-page catalog furnishes specifications in addition to necessary descriptive data on more than 16° standard types and models of both local mounted and remote bulb temperature controls. Includes general purpose, dual switch, explosion-proof and indicating type units.

Source: United Electric Controls Co.
Watertown 72, Mass.

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Portable Test Instruments

Brochure of Bulletins describe complete line of high-quality portable test instruments featuring transistor circuitry, printed wiring, and self contained battery power-supplies which give laboratory precision under adverse field conditions.

Source: Alectra Division
Consolidated Electrodynamics Corp.
Pasadena, Calif.

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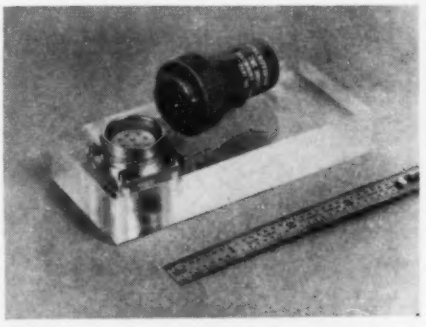

Chopper for Modular-Type Equipment

Miniature hermetically-sealed syncrverter switches for modular-type equipment functionally mate with Cannon K02-16-10SN receptacle and are nonresonant. These units operate at extremes of altitude, temperature, shock, vibration and acoustic noise. The Bristol Co., Waterbury, Conn.

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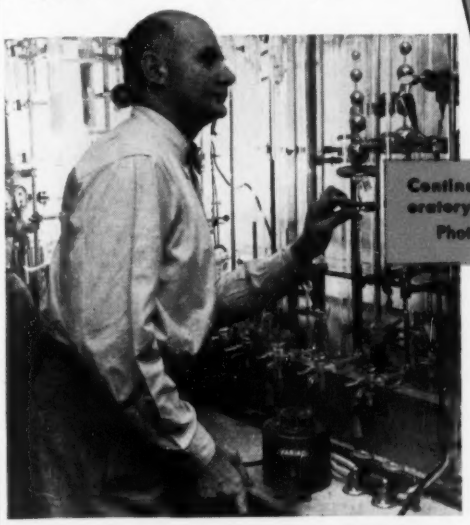

Continuously-adjustable a-c voltage for laboratory research and development work.
Photo Courtesy Bell Telephone Laboratories

Control of electric heaters and ovens in laboratories and pilot plants.
Radiation Counter Laboratories

Compact, reliable OEM component for all types of equipment and machinery.
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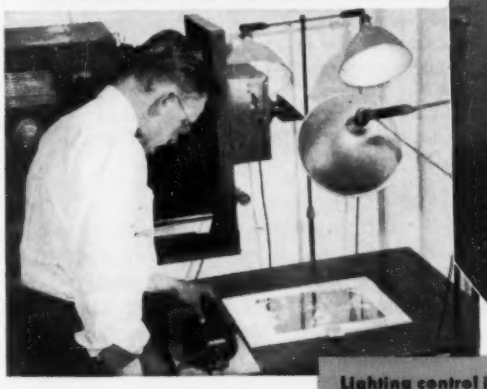
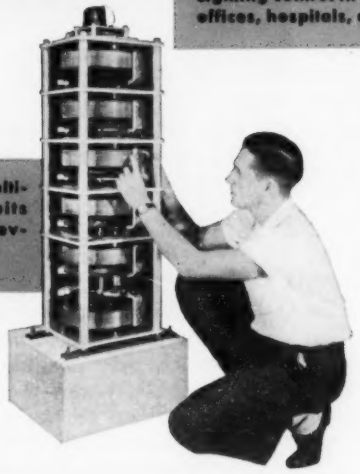


Lighting control in theaters, photographic studies, offices, hospitals, auditoriums, and public places.

Process-control tool in production operations.
Western Electric Company



Control of multi-phase circuits with aid of several Variacs.

Variacs alone, or with supplementary transformers, can solve most a-c control problems. They operate from standard 115v or 230v a-c lines and provide continuously adjustable output from zero to 17% above line voltage (135v or 270v). Variacs are available in many models with current ratings ranging from 2.4 to 50 amperes, and may be ganged for additional capacity or polyphase operation. Wherever a-c power is available, Variacs are useful for efficient control of Light . . . Heat . . . Speed . . . Mechanical and Electrical Power.

Variacs have Duratrak contact surfaces of plated silver-alloy to eliminate oxidation problems which occur with bare copper brush tracks . . . they withstand initial surges ten times rated current . . . Variacs can be easily designed into equipment for either panel, behind panel, wall, or table mounting . . . available with ball bearings, or motor driven . . . military-type Variacs are also stocked for 350- to 1200-cycle service . . . all Variacs are covered by a Two-Year Warranty, additional life insurance for designers and manufacturers who build equipment for long trouble-free service.

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MEDICAL ENGINEERING

New Kind of "Iron Lung" responds to Autonomic Demand

A machine called a Pneumotron, which can "coax" a prematurely born baby to breathe, or revive an adult too ill to breathe unaided, is being offered to hospitals by British Oxygen Gases, Medical Division, Brentford, Middlesex, England. The machine is electronically controlled and can operate in two distinct ways, automatically or on demand, according to need. For the patient suffering from prolonged respiratory paralysis—as in poliomyelitis, tetanus, head injury and so on—it will provide, on automatic circuit, completely automatic forced breathing and can operate over long periods without constant attention.

Yet the really big advance offered exclusively by the Pneumotron is its ability, on demand circuit, to respond to the slightest attempt at breathing on the part of the patient.

The Pneumotron is based on a machine developed at the Post Graduate Medical School of London; and although primarily intended for resuscitating premature babies, it has been designed to sustain and promote breathing in adult patients as well.

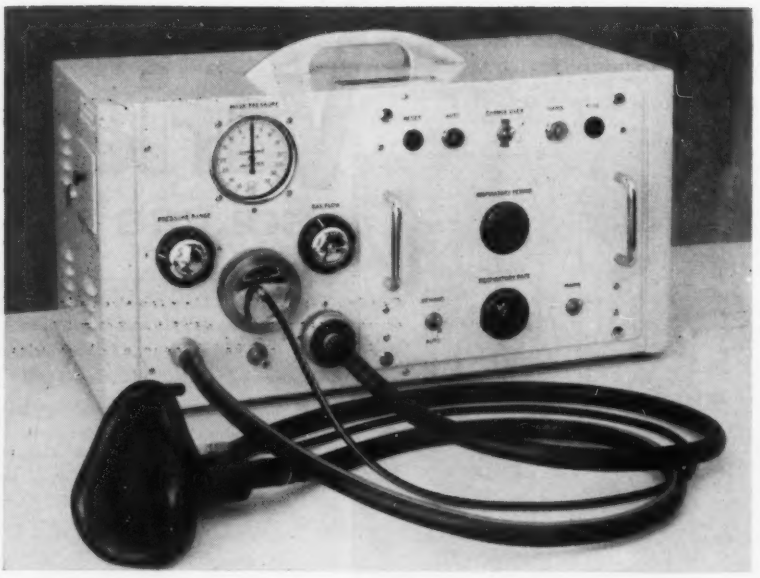
The machine's ability to respond to the patient's effort in a highly sensitive way is achieved by employing electromechanical principles. When the demand circuit is used, any faint attempt at breathing by the patient, who has the mask fitted or held to his face, creates a slight negative pressure, or suction, which moves a very sensitive diaphragm in a trigger unit. An interrupter linked to the diaphragm is thereby lifted, allowing a beam of light to shine on the germanium element of a photo-electric cell. The change of current, thus caused, "triggers" the electronic circuit and an electro-magnetic gas-delivery valve is opened, allowing oxygen (or an oxygen-nitrogen mixture) to flow to the face mask for the duration of the inhaling period. While the oxygen is flowing in through the delivery valve, the exhaling valve, also controlled electromagnetically, is closed. But as soon as the inhaling period is finished, the delivery valve closes and the expiratory valve opens, allowing the patient to exhale into the room.

The machine then "waits" for the patient's next attempt to breathe in. The patient thus has complete freedom to take his own time, to take as long as he requires to exhale and to pause, if he wants to, before breathing in again.

It is confidently anticipated that the Pneumotron will save lives and help still further to reduce the infantile mortality rate.

For forced respiration on the automatic circuit, the Pneumotron also represents a big advance on the technique of the "iron lung" which relies largely on mechanically opening and closing the lungs by means of external pressure.

When the automatic circuit is used, both the rate of breathing and the inhaling period are controlled by the machine. In one cycle the oxygen, under controlled pressure, flows to the mask during the breathing-in period. During the rest of the cycle the patient is free to exhale. Every element is readily adjusted. The rate of forced breathing can be varied from 10 to 60 respirations a minute. The time relationship between breathing in and out can similarly be varied over a wide range, from equal periods for inhaling and exhaling to five times as long for breathing out as for breathing in. The fine adjustment of all these things, as well as for the flow of gas up to a maximum of 60 litres a minute, is done by the medical attendant by the simple turn of a knob.



Electronic circuit of the Pneumotron ensures great flexibility of control. An on-off power switch is provided on the control panel and a warning lamp indicates that the electrical circuit is completed. Selection of automatic or demand circuit is by means of a two-position switch. Control of respiratory rate is achieved by means of a rotary switch, the rate being continuously variable between 10 and 60 respirations per minute. The inspiratory/expiratory ratio is similarly controlled, the range being 1:1 to 1:5. Control of gas flow is by fine adjustment flow valve, allowing variation from no flow to a maximum of 60 litres per minute. With the respiratory rate and inspiratory period established, adjustment of the flow control valve varies the volume of gas delivered. The degree of control is from a few ccs at the higher respiratory rates and shorter inspiratory periods, to several litres at the slower respiratory rates and longer inspiratory periods. Either of two pressure ranges may be selected. The maximum output pressure from the machine on each range is limited by means of a safety valve which exhausts to atmosphere. The blow-off pressure may be pre-set and locked. The higher maximum pressure is usually established at 30 cms H_2O.

An important feature of the Pneumotron is that it can not only operate on either the automatic or demand circuit at will, but there is an automatic change-over device for switching the machine from demand to automatic circuit.

Thus, if an adult patient is left without supervision for a short period and his attempt at breathing becomes too weak even for this sensitive machine to respond, the Pneumotron will automatically go over to automatic circuit and keep oxygen passing through his lungs. When, after attention, the patient is able to resume assisted breathing, the machine is re-set on demand circuit by the push of a button.

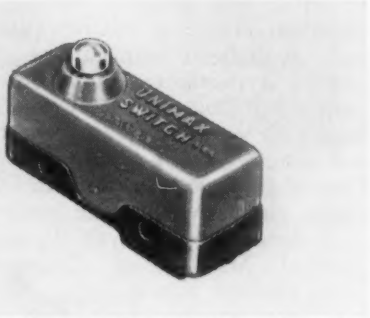
The Pneumotron is so designed as to avoid the risk of cross infection. Every part which may possibly be contaminated can be removed and sterilized. Similarly, there are safeguards against power failure. While the machine normally operates on a-c supply, provision is made for coupling to a special battery-driven d-c power supply unit which comes into use automatically in the event of a power failure.

The Pneumotron, measuring 21½ x 10½ inches, is not much bigger than a portable radio set and weighs 40 lbs.

Circle No. 51 on Inquiry Card

COMPONENTS

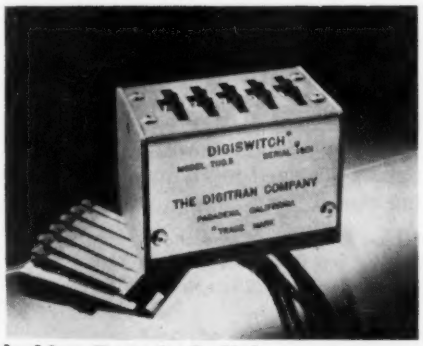
SWITCHES



Stub-Plunger Snap-Acting Switch

Snap-acting miniature switch with service life of 1 million operations has a long bearing guide for the plunger in the one-piece switch cover, assuring smooth action and high repeatability. Electrical rating is 20 amperes at 125, 250, 480 volts a-c; 0.25 amperes at 250 volts d-c, 0.50 amperes at 125 volts d-c. The switch, UL listed, can be furnished with ½ hp 125 volts a-c, 1 hp 250 volts a-c, or ¾ hp 125 volts a-c, 1½ hp 250 volts a-c. Dimensions: less than 2 inches long, 11/16 inches wide, 1-3/32 inches overall height. Unimax Switch Div., W. L. Maxson Corp., Wallingford, Conn.

Circle No. 104 on Inquiry Card



In-Line Decade Switch

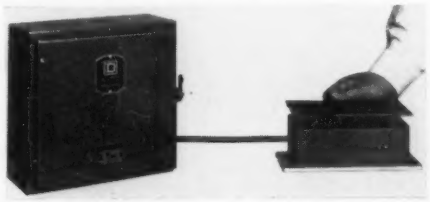
3 or 5 decade switch features single and double pole and has binary coded switch configurations for each decade. Switch allows operator to read only visible numbers, thus increasing reading ease and reducing switch setting errors. Both 3 and 5 decade switch units have contact ratings of 200 volts and 1 ampere. The unit measures 1.84 x 1.75 x 1.87 inches. Side brackets permit flush panel mounting. Digitran Co., Pasadena, Calif.

Circle No. 103 on Inquiry Card

Air-Gap Limit Switch Eliminates Physical Contact

Based on the principle of a resonant circuit, this new limit switch operates without physical contact in mill duty applications where heavy impact and shock cause mechanical limit switches to break down. It consists of three parts —a magnetic vane attached to the moving portion of the machine; a reactor unit, mounted on the stationary portion of the machine; and a standard a-c relay which opens or closes the circuit. The action of the magnetic vane passing over the reactor actuates the relay. High sensitivity permits the switch to function when the vane is within ⅞ inch of the reactor, and operation is not affected by voltage variations up to ±10 percent. Because no vacuum tubes are used, the switch can operate in the same high temperatures as does a mechanical limit switch. Electric Controller & Mfg. Co., A Division of Square D, Cleveland, Ohio.

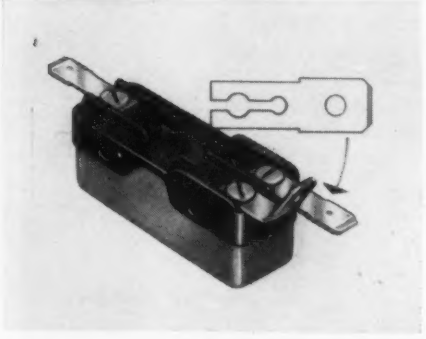
Circle No. 118 on Inquiry Card



Quick-Connect Terminals for High-Sensitivity Snap-Acting Switches

Male snap-on terminals make ultra-sensitive switches, with a wide variety of actuators, adaptable for use where quick replacement or mass production methods demand quick-connect terminals. Terminals fit between the molded barriers on the Unimax switch base and securing screw spreads the slotted end to give solid, no-turn installation that resists shock and vibration. Made of 0.32 inch half-hard brass, ¼ inch wide and indented for tight connection, these terminals are available for straight-on or up-to-90° angle connection and fit standard female quick-connect terminals. Unimax Switch Division, W. L. Maxson Corp., Wallingford, Conn.

Circle No. 112 on Inquiry Card



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ON ECONOMICAL

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At long last you can now secure beautifully bright, gleaming colors from a simple LUSTER-ON chromate dip process for your zinc plated small parts.

These are not just spotty identification colors. These are scintillating golds, yellows, blues, greens, violets, reds, brass and copper hues that will add glamor and sales appeal.

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THE *Chemical* CORPORATION

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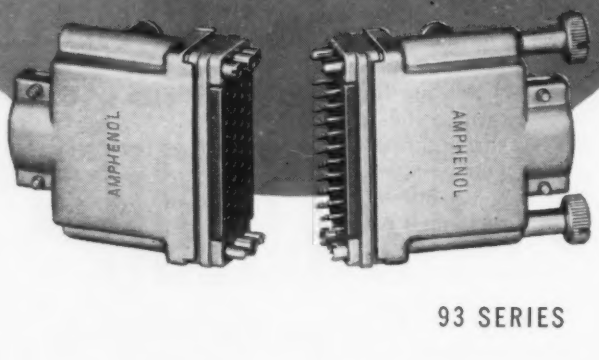
CIRCLE 22 ON INQUIRY CARD

2 new

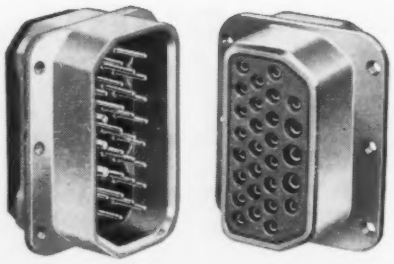
AMPHENOL

RACK & PANEL Series



93 SERIES

94 SERIES



both with POKE-HOME*contacts!

*U. S. PATENT 2,419,018

Meet 2 new additions to AMPHENOL's line of Rack & Panel connectors! The 93 and 94 Series are complete lines of standard connectors providing wide application variety. Both incorporate AMPHENOL's remarkable Poke-Home contacts that are wired separately from the connector then poked home for assembly. Poke-Home contacts are also removable for fast circuit changes or corrections.

93 SERIES 3 insert arrangements, 8 varieties of housings; 500 volts D.C. at sea level; 7½ amp size 20 contacts. Silicone rubber face gaskets. Operating temperature of 400°F. per MIL-C-8384.

94 SERIES 5 insert arrangements in 3 shell sizes; coaxial connectors in 2 inserts; 600 volts RMS at sea level; forged aluminum shells; temperature range of −76°F. to +257°F.

AMPHENOL

chicago 50, illinois

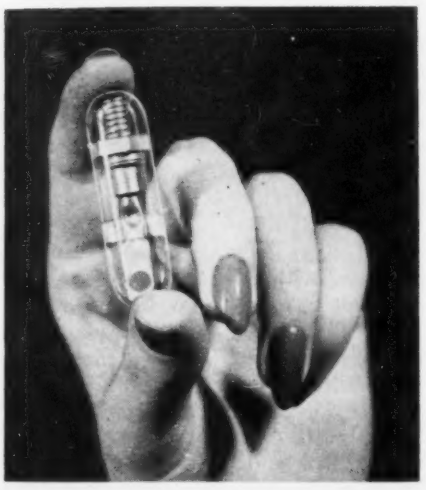
AMPHENOL ELECTRONICS CORPORATION

FOR MORE INFORMATION CIRCLE 23 ON INQUIRY CARD

Kilowatts In A Capsule

A small diffused junction silicon power rectifier rated for continuous service at 20 amperes d-c and maximum peak reverse potentials up to 400 volts has been designed specifically for d-c power supply and magnetic amplifier applications requiring reliable performance in ambient temperatures up to 150°C. It provides a high degree of power handling ability in miniature form with very low forward resistance and extremely high reverse resistance. Four of these rectifiers in a full wave bridge circuit will provide power for a 10 horsepower 230-volt d-c motor. Fansteel Metallurgical Corporation, North Chicago, Illinois.

Circle No. 108 on Inquiry Card



WORTH FILING

Plastic Tool Design Template

Set of three plastic tool-clamp templates containing over 30 different figures designed to save valuable drafting time.

Source: PIC Design Corporation
East Rockaway, L.I., New York

For your templates: Circle No. 74 on Inquiry Card

WORTH FILING

Miniature Electrical Connector Selector

Pocket-size slide-rule calculator provides complete electrical and mechanical specifications on all standard series Continental Connectors. Body molding comparator on the reverse side gives values of various properties of plastic compounds used in molding Continental Connectors.

Source: DeJur-Amsco Corporation
Long Island City, New York

For your copy: Circle No. 68 on Inquiry Card

Grate Magnet

Grate magnet has four times more collection surface than ordinary units for effective removal of tramp iron from free-flowing materials. Magnetic collecting tubes in the grate magnet have continuous poles along their entire length, thus eliminating dead spots where iron particles can slip past. Ceramic magnet material produces a powerful, uniform magnetic field between the tubes of the grate. Available in wing-type for hopper or floor installation and drawer-type for closed chutes and duct the magnet with single or double banks of collecting tubes fit most installations. Stearns Magnetic Products, Milwaukee, Wis.

Circle No. 83 on Inquiry Card

WORTH FILING

Portable Computer Center

8-page brochure describes a high precision Desk-Side Analog Computer, that provides a complete, portable computer center. Brochure gives detailed description of operational amplifiers and other standard and optional equipment, including removable patchboards, 3-way amplifiers, extra operational and computing elements, and special servo equipment.

Source: Mid-Century Instrumatic Corp.
New York 12, N.Y.

For your copy: Circle No. 69 on Inquiry Card

Microwave Ferrite Devices

Short-Form Catalog describes electrical characteristics, physical dimensions, and prices of high-power ferrite load isolators, low-power ferrite load isolators, ferrite modulators, circulators and circulator switches. Units classified as high-power are those utilizing resonant absorption principle while those in the low-power classification operate on the Faraday rotational principle.

Source: Cascade Research Division
Monogram Precision Industries Inc.
Los Gatos, California

For your copy: Circle No. 114 on Inquiry Card

WORTH FILING

Wing Nut Spec Sheets

3-page sheet of standard die cast zinc alloy threaded fastener specifications describes Junior, Senior, and Economy die cast wing nuts.

Source: Gries Reproducer Corp.
New Rochelle, New York

For your copy: Circle No. 58 on Inquiry Card

WORTH FILING

Infrared Transmitting Materials

New brochure provides revised comparative information on fifteen different infrared transmitting materials suitable for use as optical elements. Transmission curves are included for the eleven most important materials.

Source: Servo Corporation of America
New Hyde Park, New York

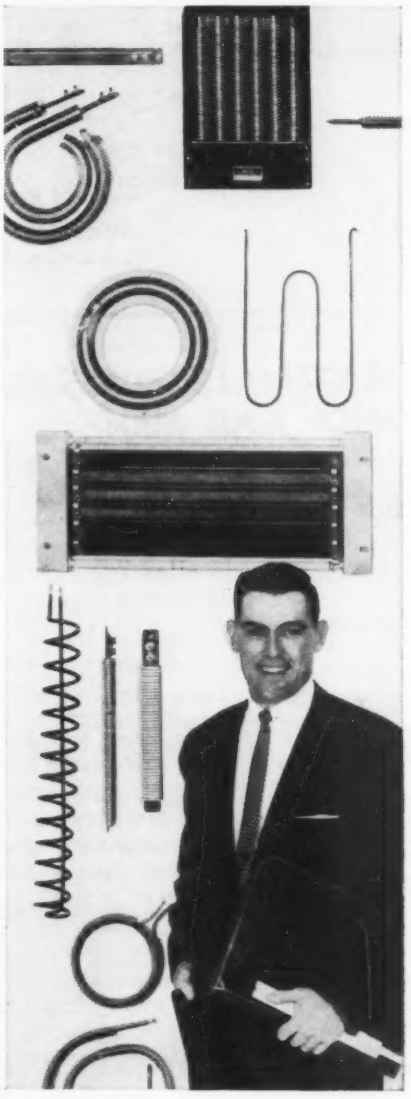
For your copy: Circle No. 67 on Inquiry Card

Control Connecting Assortment

Industrial control connecting assortment contains all tools and components for reliably interconnecting automatic controls. 3-wire detachable cable junctions with two tap-in points for interconnection of controls and associated devices, make possible quick assembly of complete wiring harnesses in any length and connector layout for one-time jobs or prototype layouts, interconnecting automation and production equipment, and electronic equipment and instruments. Installation, servicing and replacement of electrical controls and devices such as limit switches, transformers, solenoids, and electrically controlled air cylinders, etc., is greatly simplified. Alden Products Company, Brockton, Massachusetts.

Circle No. 116 on Inquiry Card

Process Air Heating?



Your Chromalox Man has the ANSWER . . .

When you need:

- clean, moisture-free heat
- precisely controlled temperatures
- additional heat to supplement existing equipment
- safe, explosion-proof heat

For finish baking, heat-treating ovens, annealing ovens, core and armature drying ovens . . . hundreds of similar applications. Operating temperatures to 1000°F. maintained by thermostat control. Standard units quickly installed in existing ducts . . . multiple circuits can be supplied for modulating heat output. Call your Chromalox representative or write today for details.

CHROMALOX Electric Heat

Edwin L. Wiegand Company
7900 Thomas Boulevard
Pittsburgh 8, Pa.

CIRCLE 24 ON INQUIRY CARD

MATERIALS

STAFF COLUMNIST

David Bandel
Associate Technical Director,
TRACERLAB, INC.

MATERIALS, MISSILES, MICE AND MEN

During the week of April 13, the 133rd National Meeting of the American Chemical Society in San Francisco offered several symposia on problems close to the heart of many an electromechanical design engineer. The good news of progress in some of the fields discussed may help shrink an ulcer or two.

HIGH PERFORMANCE MATERIALS

In one symposium on high performance materials, R. H. Thielemann of Stanford Research Institute emphasized that progress in almost every field depends upon the development of high performance materials. To satisfy the insatiable appetites of design engineers, efforts must be directed toward development of new materials with an unusual combination of properties as well as improvement of materials now in existence. High temperature performance is the crux of advancement in the power field, wherever heat engines or heat cycles are involved. Materials are needed that will permit long time operation at 2000°F and higher. Chemical and petroleum industries require materials that resist chemical attack at elevated temperatures. Military requirements for higher performance materials of all types can never be satisfied. High performance alloys were discussed by F. S. Badger of Haynes Stellite Co. The problem of increased operating temperatures in missile and turbines is increasing in magnitude. Present temperature limits for nickel and cobalt-based alloys is 2000°F. These limitations are forcing more intensive development of reactive and refractory metals such as titanium, molybdenum, tungsten, tantalum, columbium, and vanadium which like the metal ceramics, have corrosion resistance under conditions of temperature and pressure beyond the useful range of nickel and cobalt-based alloys.

M. P. Bennett of Gladding, McBean and Co. pointed out that high temperature ceramics are available in 3 general ranges: 2000°F, 3000°F and above 3500°F. In each temperature range various ceramic materials meet specific requirements of insulation, refractoriness, chemical resistance, electrical and mechanical properties.

Adhesives and adhesion mechanisms are definitely part of high performance materials. D. W. Elam and E. E. Elam singled out the role adhesives are playing in aircraft construction. The new supersonic bomber, the B-58, is largely adhesive bonded. For the future we need not only new and better adhesives as such, but a better understanding of adhesion itself; how it relates to composition of matter and how we can apply this knowledge to design the structures we can only envision at this time.

Observations on the salt spray corrosion resistance of aluminum panels bonded with adhesives were reported by F. J. Riel, S. E. Susman, B. Stewart and R. Brewer of Narmco, Inc. Edges of test panels freshly cut or trimmed to remove overflow were found to have corrosion spots at certain points along the trimmed edge. Corrosion progressed inward from the spots, apparently along the interface between the metal and adhesive. Other areas along the trimmed edge were unaffected and adhesion between the metal and adhesive was unaffected. Some panels corroded more than others but in no case did corrosion penetrate inward equally from all trimmed edge areas.

Some data indicate that initiation of corrosion along a trimmed edge is a function of the surface condition of the aluminum and that for the alloy investigated, 2024-T-3 clad, some areas on the aluminum surface contain loosely adhering flakes of aluminum. It is postulated that these isolated areas of loosely adhering aluminum flakes provide an entry for corrosive vapors and liquids. When such an area occurs at the trimmed edge of a bonded specimen, corrosion starts at this point and proceeds inward by diffusion through the porous aluminum structure. Once initiated, the build-up of corrosion products inside the glue line produces a wedgelike effect which promotes further diffusion or corrosive fluids along the metal adhesive interface.

Adhesive joints, according to J. J. Bikerman of M. I. T., do not break along an interface; they rupture either in one of the adherends or in the adhesive film. A cohesional failure is the rule for industrial joints. Force required to strip glued ribbons was derived mathematically for the Newtonian liquid and Hookean solid cases. If failure does occur in one of the interface layers, substances forming or capable or forming such layers must be removed before a proper joint can be achieved. Removal of oxides by flux in soldering is a familiar illustration of this rule. Logical application of this theory to plastics has resulted in polyethylenes that adhere readily to almost all solid surfaces tested.

FUELS

The use of high energy fuels to increase the power output of aircraft and automobile engines was reported in two papers. Dr. Paul F. Winternitz of New York University stated that the use of boron compounds as high energy fuels will extend the range of aircraft by 25 to 50 percent, revolutionizing the design of jets and rockets.

Comparison of data in recent research shows that boron compounds are superior in this respect to any other fuels for air-breathing engines, and most likely also for rockets.

Calculations of maximum range for jets and rockets, and the maximum height that can be reached by a rocket, prove that both horizontal and vertical limits are directly proportional to the energy release in the combustion of the fuel.

Measurements of the heat released when a pound of each chemical element burns, as in a jet, and the heat released when each element oxidizes, as in a rocket, indicate that boron ranks third among the elements for amount of heat released in both cases.

Hydrogen is in first place for air-breathing engines by a great margin but falls far below for rocket engines. Because of performance limitations of other top-ranking elements, hydrogen has the highest "specific impulse" in a rocket. Unfortunately, it has very unsatisfactory physical properties. It is, therefore, advantageous to use hydrogen in combination with other elements that can act as hydrogen carriers.

Lithium and beryllium, the other elements at the top of the energy scale, have to be excluded as fuels for large-scale applications because no liquid or suitable solid compound of these elements is known. In addition, they can carry much less hydrogen per pound than can boron.

Boron is an excellent hydrogen carrier and, possibly just as important, has extreme chemical versatility. As a result of this versatility the physical properties of boron compounds can be tailored to meet most requirements for boron fuels. The need to meet these requirements has led to the discovery of entirely new classes of boron compounds and of numerous unique and unexpected chemical reactions.

Although these considerations may be crude, they show that compounds consisting primarily of hydrogen attached to boron should give the most desirable propellants and certainly be superior to conventional hydrocarbon fuels.

Radical flying machines would be propelled by jets operating on the chemical energy of the thin air at altitudes above 60 miles. The ultimate success of this kind of flight will depend primarily on the speed with which single oxygen atoms of the upper air can be made to pair off to form molecules of oxygen gas. The preliminary design of a ramjet atomic-oxygen power plant has been carried out in detail in pioneering research under contract with the Air Force Office of Scientific Research. It has been shown that thrusts can be achieved that compare favorably with the expected frictional drag at these altitudes. However, at speeds of about 6,000 miles per hour, the lift provided by a square foot of wing surface would be only about one ounce.

In the upper atmosphere, the fierce rays of the sun break up nearly all the oxygen molecules into single atoms. Since these atoms release large amounts of energy when they recombine into molecules, this thin air serves as an unlimited storehouse for the energy of the sun, waiting to be used for propulsion or other purposes.

The atomic oxygen may be made to recombine by two methods: either by passing it over a catalyst or simply by compressing the gas stream. Since the density of the atmosphere at an altitude of 60 miles is extremely low (about one millionth of its sea-level value), the available thrust is quite small. But the frictional drag is very small for the same reason, and a ramjet flying several times the speed of sound could easily produce enough thrust to overcome the drag. The ramjet would have to be made of extremely light materials, such as thin metal foil, since the lift produced per unit area of wing surface is so small.

Professor Paul Hartech of Rensselaer Polytechnic Institute is investigating the possibility of constructing a vehicle of this type to fly at about twice the speed of sound, using a catalytic power plant. Since it would not have to carry any fuel, it could stay in the air indefinitely. Because of the extreme lightweight construction required, such a vehicle would have to be unmanned. It would be useful for such purposes as a reflector for television or microwave signals, weather surveillance, or safety stations.

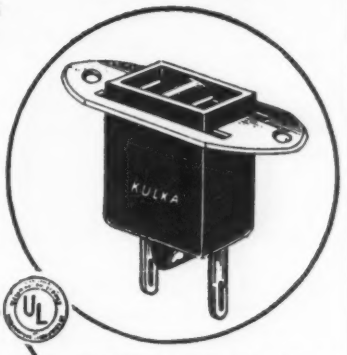
At Aerojet-General a different approach to the problem is being investigated. If the atomic oxygen ramjet can be made to fly at orbital speed (18,000 miles per hour) no lift will be required, and heavy payloads of men and instruments can be carried in orbit at 60 miles altitude indefinitely, provided the drag can be made smaller than the available thrust. No fuel would be required. The atomic-oxygen satellite would extract sufficient energy from the atmosphere to overcome the drag. Preliminary calculations indicate that it will not be easy to reduce the drag to this level, but the possibility is not yet definitely excluded.

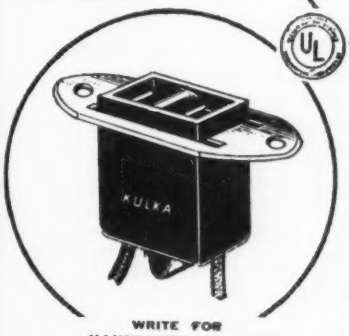
The inner needs of design engineers humped over the board with a tough problem received sympathetic consideration by the chemists. Dr. A. R. Surrey of the Sterling-Winthrop Research Institute announced the news of a new "triple threat" tranquilizer. This new drug, chlormethanzanone, has been given the more civilized trade name of Trancopal. It is estimated to be three times more effective than the best known tranquilizers in tests with mice. The old question, "Are you a man or a mouse" may take on new significance after the completion of clinical tests on humans.

New Miniature POWER OUTLETS
For Small Electrical and Electronic Units

- SMALLEST MADE
- TAKE STANDARD PLUG
- MOUNT FROM TOP OR BOTTOM OF FLAT BRACKET
- CHOICE PRE-WIRED STYLE, OR WITH SOLDERING TERMINALS
- PHENOLIC BLOCK HAS BARRIER TO PREVENT SHORTS
- AC and DC

SHOWN FULL SIZE





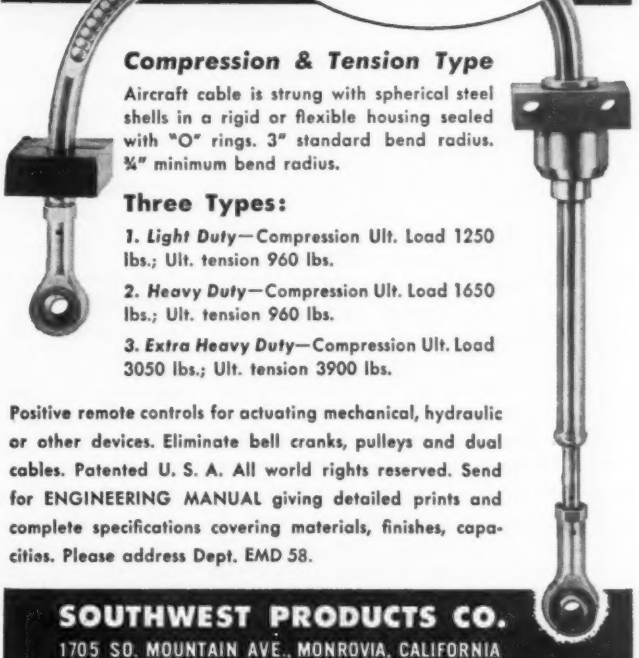
WRITE FOR ILLUSTRATED BULLETIN.

No. 221 (above) with soldering terminals and steel bracket with # 6 clearance mounting holes. Also No. 222 with 6-32 tapped mounting holes. No. 223 (left) with 8" #14 or #16 plastic wire leads and steel bracket with #6 clearance mounting holes. Also No. 224 with 6-32 tapped mounting holes.

KULKA ELECTRIC CORPORATION
Manufacturers of Electrical Wiring Devices
MOUNT VERNON, N. Y.

FOR MORE INFORMATION CIRCLE 25 ON INQUIRY CARD

push-pull CONTROLS



Compression & Tension Type

Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.

Three Types:

1. *Light Duty*—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. *Heavy Duty*—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
3. *Extra Heavy Duty*—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.

Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD 58.

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

FOR MORE INFORMATION CIRCLE 26 ON INQUIRY CARD

BOOK REVIEWS

Ideas, Inventions and Patents

Robert A. Buckles
270 pages, $5.95, John Wiley & Sons, Inc., New York

Intended primarily for engineers and scientists engaged in research and development activities and for business men engaged in planning and managing industrial enterprises in which inventions, patents and trademarks play a role, this book presents, in broad general outlines, the fundamental principles and philosophy of the laws respecting intellectual property for the purpose of pointing the way to more effective protection and exploitation of ideas and inventions. The author unquestionably achieves his objective in an easy-to-read style that avoids the usual legal jargon. He covers the principles that underlie patents in all fields of technology—mechanical, electrical, chemical, nuclear—and gives examples of specific applications in each area. In addition, he takes you through a step-by-step case history of a simple invention presenting you with the normal kinds of happy and unhappy experiences you may have had with the patent office or with patent attorneys.

Logical Design of Digital Computers

Montgomery Phister, Jr.
408 pages, $10.50, John Wiley & Sons, Inc., New York

The author has organized this book to form the equivalent basis of a one- or two-semester course in computer logic, introducing the reader to the art and science of designing digital systems. He describes techniques, not computers, and presents the practical application of these techniques to interested engineers, mathematicians, and physicists. The book assumes no previous experience with computers. The author's aim is to provide you with information, tools and procedures needed to carry out the complete logical design of a general or special purpose computer. The circuit components discussed in the book are almost entirely synchronous—that is, the signal wires connecting circuit elements contain meaningful information only at discreet intervals of time, usually called clock-pulse times. The author feels that, although most of the current literature on computers refers to other methods of design, his particular experience in computer work has convinced him that there are a great many advantages to be gained in carrying out design in the way that he describes it in his book. He feels that computer systems now desired are so complicated and the logical properties of circuit components are so intricate that it is often difficult to derive computer circuits without using Boolean algebra. And although much work is being done on the synthesis and analysis of synchronous computer circuits, such circuits have inherent timing problems which tend to make their interconnection difficult and which thus obscure their intended functions. The author includes detailed discussions of the Veitch Diagram method of simplification of Boolean equations; the "difference-equation" approach to memory elements; the Huffman-Moore model of digital systems; the complete solutions to flip-flop input equations; and a mathematical introduction to Boolean algebra.

Elements of Heat Transfer

Max Jacob and George A. Hawkins
Third edition, 315 pages, $6.75, John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y.

This third edition replaces its predecessor, *Elements of Heat Transfer and Insulation*. It emphasizes basic principles and their applications to simple problems. Basically, the differences between this third edition and its predecessor are: new table on thermoconductivity of liquid metals; added section on the use of equivalent circuits for the solution of problems; information on one type of thermoanalyzers; additional material on the analysis of engineering systems; new sections on the heating of liquid metals and turbulent flow-through pipes, hydro-dynamic and thermal boundary layers, convective heat transfer high velocities and the analogy between electrical and thermal circuits for convective heat transfers; a new section on heat exchanger effectiveness ratio; expanded chapter on heat transfer and condensing and boiling, to include the differences between nuclear partial film, and film boiling; a concise section on gas radiation; new coverage of mass transfer and the similarity between heat and mass transfer.

The Cerebral Cortex and the Internal Organs

Konstantin M. Bykov, M.D., and W. Horsley Gantt, M.D.
448 pages, $15.00, Chemical Publishing Company, Inc., 212 Fifth Avenue, N. Y.

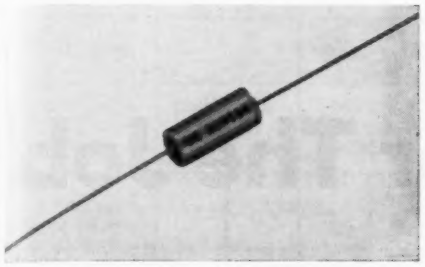
Dr. Bykov is a member of the USSR Academy of Sciences, Director of Naval Military Academy, Leningrad, and former collaborator with Pavlov at the Institute of Experimental Medicine. The book has been translated and edited by Dr. Gantt who was also a collaborator in Pavlov's laboratories from 1923 to 1929, a Director of the Pavlovian laboratory and Associate Professor of Psychiatry, Johns Hopkins University. Engineers engaged in working with human factors in design will find this translation of use as a reference text. The book covers the principles governing the adaptation of the individual to his external and internal environment. It shows how the functions of the internal organs, endocrine glands, and general metabolism are integrated through the suprasegmental nervous system. It explains how normal and pathological functions of the animal and human organism can be studied by strictly objective physiological methods. It describes the role of the cerebral cortex in the coordination and regulation of the complex processes occurring in the special functional acts of the viscera; how the impulses arising in the internal organs affect the cortex; how the internal environment influences human behavior; and how vegetative processes become merged with consciousness.

Applied Analysis

Cornelius Lanczos
539 pages $9.00, Prentice-Hall, Inc., 70 5th Avenue, New York 11, N. Y.

Dr. Lanczos concentrates in the large area between the "pure analyst" who pursues his ideas in a world of purely theoretical contructions, and the "numerical analyst" who translates the processes of analysis into machine operations. His objective is the analysis and design of finite processes which approximate the solution of an analytical problem. "To design procedures which will effectively minimize the error in a small number of setups," he writes, "and which will estimate the error with sufficient accuracy is not a matter of practical interest only but a matter of scientific interest as well." And he devotes the book largely to such problems. His approach is more narrative than formal and illuminates broad avenues of thought on a limited number of topics rather than examine the phenomena of minuscule significance. In this book, in effect, he steps back from the extremes of specialization into that center where all is related and integrated into a meaningful whole. He has made this departure from the vigorously pragmatic approach now current, as he explains in his preface, because he believes that in the final analysis mathematics must be understood before it can be applied. The book offers the engineer, the practicing engineer and the physicist an opportunity to think deeply about the inner significance of the mathematical relations in which the procedures he uses daily are premised.

COMPONENTS



Axial Lead Silicon Zener Diodes

New silicon Zener diodes with axial leads offer the space and weight advantages of a sub-miniature package measuring only 0.688″ x 0.032″, with a lead length of 1½ inch. The manufacturer states these units are not position-sensitive, and may be inserted by automatic machines on an assembly line basis. An efficient heat-dissipating path from the Zener diode junction is built-in, to assure better heat transfer, a conservative power rating of up to 200 mw at 25 degrees C, and a high safety factor in critical applications. Additional characteristics claimed by manufacturer: all-welded construction, minimum Zener impedance, low saturation current, superior voltage regulation through abrupt breakdown, and physical size within that of a standard 1-watt resistor. Semiconductor Products, Inc., Phoenix, Arizona.

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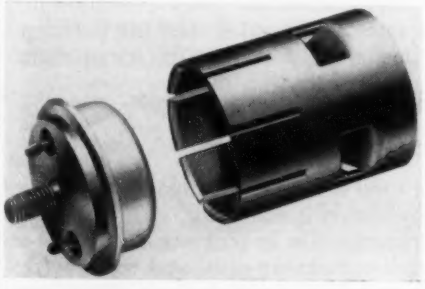
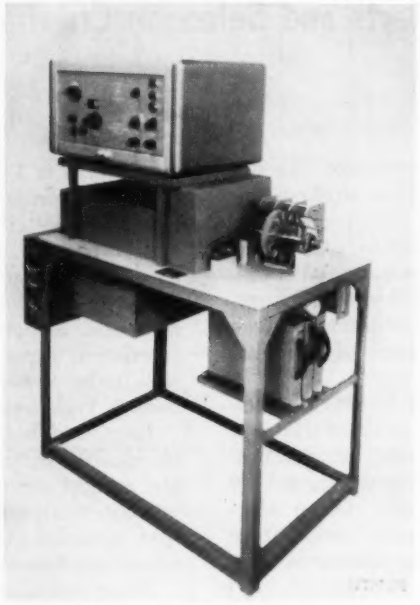


Heat Dissipators for Power Transistors

Heat dissipators have been designed for power transistors to provide substantial temperature reductions in applications where the transistor cases cannot be grounded to the equipment heat sink. Slip-on installation of the dissipator immediately starts the cycle of heat dissipation from the transistor by radiation and convection. Due to its light weight and small size, the heat dissipator proves compatible with efficient use of space in compact design trends. It eliminates the need for large, thick, finned and usually heavier surface areas for heat dissipation. Excess heat is prevented from reaching printed circuit boards. The heat dissipators are made of aluminum with a black anodize finish and are tab-perforated near the upper end to increase convective cooling. Attaching end is slotted and formed so as to provide a tight spring friction fit to the transistor. Present production units are available to fit 2N174 and 2N301A power transistors or transistors having the same case dimensions. International Electronic Research Corporation, Burbank, Calif.

Circle No. 119 on Inquiry Card



1 MC Automatic Capacitance Bridge

High-speed 1 Mc. automatic capacitance limit bridge complete in itself, with built-in precision standards does not require any external capacitors. Simple and fast to operate, with no knobs or dials to turn and no meters to read, the unit can be used as a simple indicator with green light indicating test capacitor within tolerance; and red and amber lights indicating out of tolerance units. Units are available with semi or fully automatic component feeding and sorting mechanisms. Industrial Instruments, Inc., Cedar Grove, New Jersey

Circle No. 106 on Inquiry Card

WORTH FILING

Stable Voltage Source

6-page brochure gives information on Elin precision power oscillators for use as ultra-stable voltage sources in a wide variety of electronic systems. Additional Elin instruments described include: a time correlation system, bridge channel tester and a unity gain power amplifier for airborne use.

Source: Electronics International Co.
Burbank, California

For your copy: Circle No. 73 on Inquiry Card

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DESIGN TIME SAVER

The Right Battery For The Job

Performance Charts and Selection Criteria for Batteries

A battery is not as simple as a resistor or capacitor. To determine its characteristics many factors must be studied—the nature of the electrolyte, compatibility of active materials, ability of separators to mechanically separate plates and withstand attack by the oxidizing and reducing agents, etc. Some characteristics are difficult or impossible to measure. Shelf life, for example, cannot be quickly determined since a battery stores electrical energy in the form of chemical energy.

Many factors are critical in present-day batteries which may be called on to operate under extremes of climatic conditions such as shock, vibration, altitude, temperature and humidity; and under physical limitations imposed by certain confined or odd-shaped spaces, etc. Often electronic requirements specify extremely wide temperature ranges and at the same time demand very narrow voltage ranges.

The performance of a battery depends in great part upon the temperatures at which it operates. Low temperatures effect all batteries in varying degrees. Since a battery furnishes electrical energy by virtue of chemical reaction, and the rate of reaction is directly proportional to temperature, the rate of electrical energy supplied is decreased at low temperatures. A battery will still function at low temperature, however, provided the rate of discharge is within the scope of the chemical reaction.

The following sections describe the general characteristics of current types of commercial batteries and discusses their relative advantages for various applications.

RECHARGEABLE BATTERIES

Rechargeable batteries are designed to be used for a number of discharge-recharge cycles. As a result, they can be tested before use to insure reliability and are more economical than primaries which cannot be recharged. Used intermittently, they have long life.

Two types of rechargeable—or secondary—batteries are made: acid electrolyte (lead-acid) batteries, which have to be kept charged to maintain full capacity, and alkaline electrolyte (silver-zinc, nickel-cadmium and silver-cadmium) batteries, which may be stored in the discharged condition for long periods without maintenance and, once charged, can stand much longer until used.

For normal field applications, however, maintenance required for acid-electrolyte batteries between charge and use is not a greatly objectionable feature.

Silver-zinc. Of all the rechargeable batteries the silver-zinc type is lightest and most powerful, and the one with the flattest voltage. Compared to other batteries with equal capacity, it is 1/5 to 1/6 the size and weight of lead-acid or nickel-cadmium batteries, and 1/2 to 1/3 that of silver-cadmium batteries. It takes high peak loads, operates efficiently over a wide temperature range and maintains its capacity in storage.

Nickel-cadmium batteries have longer life than other rechargeable batteries. They have good temperature characteristics, especially at low temperatures and stand up well under abuse and high accelerations. Their main drawback is high weight-watts ratio.

Lead-acid batteries are the most inexpensive of the rechargeable batteries. They are used mainly where space and weight are not important factors and frequent charges or float service are required. Their bulk is approximately that of nickel-cadmium units except for high voltage units which are heavier and larger.

Silver-cadmium batteries are the most recent of the rechargeable batteries. Used where space and weight are important factors, they combine some of the best features of the silver-zinc and nickel-cadmium batteries, and have longer life than the silver-zinc units. They provide a high energy output at low rates, an extended shelf life in charged or uncharged condition and flat voltage discharge characteristics.

PRIMARY BATTERIES

Primary batteries are used when long storage life is required or when one-time application is called for.

Two types of primaries are made: standard (pre-activated, completely self-contained) units and reserve (dry-type) units that must be activated with the proper electrolyte at time of use.

RESERVE PRIMARIES

Reserve primaries are suitable where great energy and power are required. They can be stored economically in dry condition indefinitely until time of use and then drawn upon rapidly. Main production types are the silver-zinc; silver-chloride-magnesium, water activated; and cuprous-chloride-magnesium, water-activated primaries.

Silver-zinc primaries have the highest energy rating. They are the only primaries that can be discharged at really high as well as low rates. They can be instantly activated.

Silver-chloride-magnesium primaries that use inert spacers to separate the anode and cathode and must be continuously submerged in water to operate have short life at high voltages. Those that use absorbent material as sepa-

TABLE I Rechargeable Batteries . . . Performance Characteristics

Type	SILVER ZINC				SILVER CADMIUM				NICKEL CADMIUM				LEAD ACID			
AH Rating	5		85		5		60		4		80					
Dimensions H-W-D (in) Weight (oz)	2.91 x 2.08 x 0.785 4.5		9.44 x 2.5 x 0.5 58.0		2.91 x 2.08 x 0.785 5.0		3.855 x 2.73 x 1.37 42.5		2.375 x 2.875 x 0.625 5.6		3 x 8.625 x 2.4 100					
Discharge Rate (Amps)	0.5	5	100	600	0.5	5	6	60	0.5	10	10	100	0.5	10	10	10
WH/lb at 80°F	46.0	34.5	57.4	27.7	30.7	21.0	34.8	24.5	..	9.1	11.4	8.4	10.8	4.7	12.2	4.1
0°F	42.6	21.8	56.1	25.6	23.9	16.5	32.2	20.8	..	6.2	9.2	..	5.6	1.4	6.5	..
—40°F	4.86	2.52	30.8	22.1	12.3	6.3	14.0	10.7	..	2.0	6.7	..	3.1	0.24	3.1	..
WH/in³ at 80°F	3.19	2.45	4.66	2.24	2.37	1.62	3.72	2.60	..	0.65	0.87	0.64	0.76	0.33	0.91	0.31
0°F	2.96	1.54	4.57	2.08	1.85	1.27	3.46	2.22	..	0.45	0.70	..	0.40	0.10	0.48	..
—40°F	0.34	0.18	2.51	1.80	0.95	0.48	1.89	1.04	..	0.14	0.51	..	0.22	0.02	0.23	..
Volt. MidPt at 80°F	1.54	1.40	1.48	1.21	1.08	1.06	1.00	1.10	..	1.11	1.23	1.17	1.95	1.81	1.92	1.70
0°F	1.48	1.29	1.44	1.14	1.03	0.98	0.94	1.09	..	1.05	1.16	..	1.89	1.60	1.89	..
—40°F	1.10	0.78	1.32	1.14	0.92	0.74	0.89	1.00	..	1.05	1.14	..	1.85	1.40	1.82	..
TIME LIFE	up to 2 years				up to 3 years				up to 20 years							
CYCLE LIFE	up to 20 cycles				up to 500 cycles				up to 1000 cycles							

TABLE II
Summary of Advantages and Limitations of Rechargeable Battery Types

SILVER ZINC
Advantages: High efficiency. High specific energy and power. Extremely good high rate capabilities. Mechanical ruggedness. One year shelf life, but can be dry charged.
Limitations: Can be damaged by overcharge. Relatively poor low temperature performance. Comparatively short life. Poor shelf life.

SILVER CADMIUM
Advantages: High efficiency. High specific energy and power. High rate capabilities. Mechanical ruggedness. Unaffected by overcharging.
Limitations: Lower cell voltage than other types.

NICKEL CADMIUM
Advantages: Maintenance free (sealed cells are available). Very rugged. Reliable long cycle life. Works well at low temperatures. Easily re-charged, Hi peak currents (up to 20 times capacity). Indefinite storage.
Limitations: Relatively Heavy

LEAD ACID
Advantages: Inexpensive
Limitations: Relatively heavy, poor low temp characteristics.

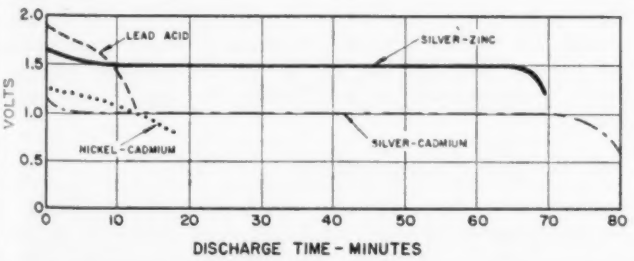

Fig 4—*Discharge Characteristics* of different types of production rechargeable batteries of equal weight delivering the same current.

TABLE III Reserve Primary Batteries . . . Performance Characteristics

TYPE (2AH)	Silver-Zinc (Separate electrolyte and gas tanks)		Silver Chloride Magnesium		Cuprous Chloride Magnesium	
Discharge Rate (Amp)	2.3	12.5	0.32	1.6	0.27	0.366
WH/lb, 80°F	24.9	19	22	22	22	15
WH/in³, 80°F	1.70	1.35	1.22	1.40	1.00	0 80
Volt. Mid-Pt., 80°F	1.40	1.23	1.58	1.50	1.35	1.31
Dry Shelf Life	Up to 5 years					

TABLE IV Standard Primary Batteries Performance Characteristics

TYPE	Leclanche Dry Cells		Mercury Cells	
Cell Capacity (AH)	0.4	3.4	1.0	2.4
Discharge Rate (Amp)	0.05	0.25	0.05	0.25
WH/lb—113°F	..	..	52.5	44.0
80°F	5.80	7.45	44.0	15.0
32°F	..	2.8	..	..
WH/in³—113°F	..	..	7.1	7.4
80°F	0.46	0.59	5.9	2.6
32°F	..	0.23	..	..
Volt. Mid-Pt.—113°F	..	..	1.18	1.05
80°F	1.40	1.45	1.18	1.00
32°F	..	1.30	..	..
Dry Shelf Life			Up to 2 years	

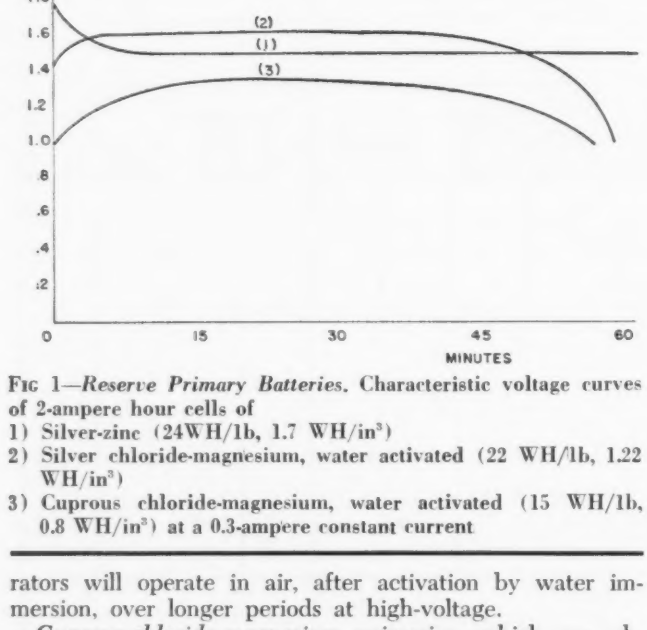

Fig 1—*Reserve Primary Batteries.* Characteristic voltage curves of 2-ampere hour cells of
1) Silver-zinc (24WH/lb, 1.7 WH/in³)
2) Silver chloride-magnesium, water activated (22 WH/lb, 1.22 WH/in³)
3) Cuprous chloride-magnesium, water activated (15 WH/lb, 0.8 WH/in³) at a 0.3-ampere constant current

rators will operate in air, after activation by water immersion, over longer periods at high-voltage.

Cuprous-chloride-magnesium primaries, which use absorbent material as separators, operate in air after activation by water immersion.

STANDARD PRIMARIES

Standard primaries are applicable where total energy requirements are relatively low. Since their shelf life depends upon temperature and general climatic conditions, a small amount of checking and maintenance is required to ensure their availability when needed. Best-known of these types are the Leclanche (dry cells) and mercury cells.

Leclanche batteries have great ecenomy in operation. They are used where low rates of discharge are needed, wide ranges of voltage are allowable and size and weight are not important.

Mercury batteries, which provide much higher rates of discharge and closer voltage regulation than dry cells, are used where size and weight are more important factors than cost. They perform well at very high temperatures, but are sensitive to low temperatures. They have good resistance to impact and acceleration.

CHOICE OF BATTERY

The preceding paragraphs describing the general characteristics of available types of batteries indicate broadly the relative advantages of each type. Tables I, II, III and IV and Figs 1,2,3, and 4 summarize the performance characteristics of these types as a basis for choice of battery for a specific application. How to use these tables can best be indicated by examples.

Suppose you have an application requiring approximately 40 wh/lb in a volume of 2 wh/in³ and that the energy dissipation must be in a few minutes in one case and in a few hours in another. Also suppose that this is to be a one-shot application.

Looking at Tables III and IV we find that the low-rate application could be met by a silver-zinc or a mercury-cell primary battery. Looking at Table I we find that both high-rate and low-rate discharges can be accomplished with a silver-zinc rechargeable battery.

We have a choice therefore of the silver-zinc or the mercury-cell for low-rate discharges, but only the silver-zinc for both high-rate and low-rate discharges.

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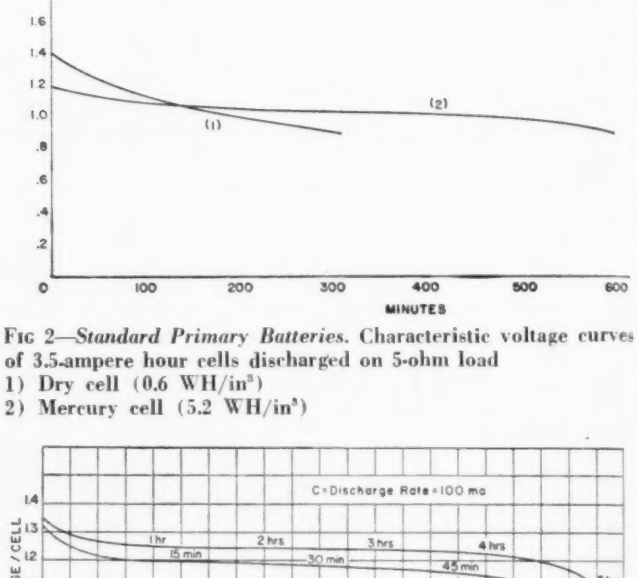

Fig 2—*Standard Primary Batteries.* Characteristic voltage curves of 3.5-ampere hour cells discharged on 5-ohm load
1) Dry cell (0.6 WH/in³)
2) Mercury cell (5.2 WH/in³)

Fig 5–Typical discharge curves of nickel cadmium button cell batteries.

Suppose further that the low operating temperature requirement is 32°F. We see from the tables the only system that meets the temperature requirements and the wh/lb specifications is the silver-zinc rechargeable system.

In this case, however, actual voltages would be lower than at room temperatures. Accordingly, the next step is to determine what voltage tolerances are possible in the system under design. If voltage tolerances are small such that operating temperatures are restrictive, battery size must be increased or the battery maintained in a narrow range of temperatures through the use of heaters. Generally speaking, most equipment will operate over a fairly wide range of voltages. For example, the 6.3-volt tube will operate between the limits of 5.6 to 7.1 volts, allowing operation over wider temperature range as well as a smaller-size battery. Thus a realistic approach to tolerances is important in the design of compact equipment.

In choosing a battery for any application, voltage level requirements must be considered. For this purpose the wh/lb figure can be converted into terms of voltage and current to find the battery with necessary rating. Practically all systems require both a low and a high voltage supply: 6, 12 or 28-volts for basic equipment and high-voltage for the "B" supply. In many of these applications low-voltage batteries can be used, with rectifier systems, either transistorized or solid state, to supply the high voltage.

THE OUTLOOK IN BATTERIES

In the present trend toward miniaturization, new kinds of electrical power sources are being used in place of batteries. Among the new developments presently being evaluated, are solar and nuclear energy converters, erroneously called batteries. The solar converter obtains electrical energy from light. In most applications for this

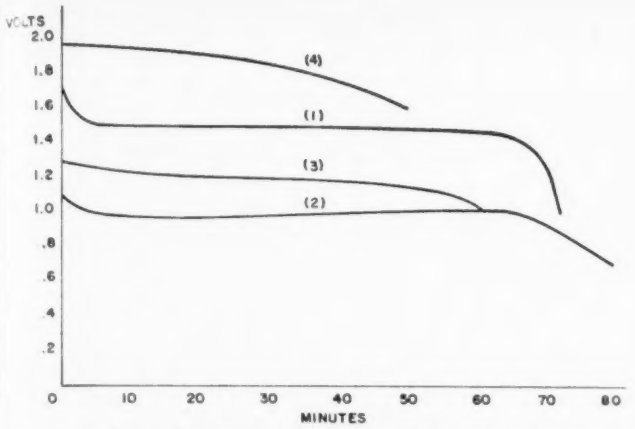

FIG 3—*Rechargeable Batteries.* **Characteristic voltage curves of 60-ampere hour cells discharged at a 50-ampere constant current rate**
1) Silver-zinc (42.2 WH/lb, 2.8 WH/in³)
2) Silver-cadmium (30.0 WH/lb, 2.7 WH/in³)
3) Nickel-cadmium (10.3 WH/lb, 0.78 WH/in³)
4) Lead-acid (7.5 WH/lb, 0.56 WH/in³)

device a secondary battery is required to store energy for use during dark periods. The nuclear system, which furnishes a very low level of energy in the order of microamperes is suitable for charging condensers to obtain stored energy. In both cases the low energy available per unit of area is such that its use in present miniaturized equipment is somewhat limited.

For many missile applications the trend has been to the silver-zinc system, both in the primary and secondary batteries. For general portable applications where transistorized equipment is used, specially-designed air-depolarized cells, mercury cells and silver-zinc secondary batteries are being specified. Substitution of magnesium for zinc in the negative in the conventional Leclanche cell has resulted in an output approximately three to four times that of the standard dry cell. This development is still in the evaluation stage.

The size requirements for the various types of batteries used in miniaturized electronic equipment and transistorized equipment has necessitated the development of extremely small cells. Figure 5 shows typical discharge curves for a nickel cadmium button cell battery.

During the past two years efforts have been concentrated on development of a mechanical type of auxiliary power unit of smaller volume that could replace batteries. However, as in the initial stages of development in the battery field, there are still many problems to be solved in the APU8s development program.

For extremely high output for very short time intervals batteries have the advantage. They are more efficient than auxiliary power units up to the point where horsepower in excess of 25 to 30 hp is required, where auxiliary power units seem more advantageous. Transverter and interverter units that develop high-voltage sources from low-voltage battery sources with an extremely high efficiency of about 85 percent, are now being made commercially available. Batteries combined with these units may form efficient power packages that could easily replace standard auxiliary power units.

With continued new developments in chemistry and in materials, such as plastics and metals, the battery industry is now in a position to develop items which hold great promise. During the next few years the possibilities of very reduced sizes in batteries, heretofore considered quite impractical, will become very real.

Information for this article was obtained from Yardney Electric Corp. and Gulton Industries, Inc.

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MARTIN E. KAGAN
Martin E. Kagan is Vice President of Yardney Electric Corp.

FEASIBLE FANTASY?

Just a few decades ago the bulk of American business and industrial enterprises was managed predominantly by men with a legal or business background. The engineer turned executive was the exception rather than the rule. However, slowly, by choice or compulsion, business has called upon the technically trained to assume the burden of responsibility for running the whole show. I don't know what the statistics are, but one does not have to reach far for companies whose top executives are engineers. Although a more scientific approach to management is evident because of this change, management of the economy as a whole has had little scientific benefit in its growth and development. Perhaps in the vast jungle of commerce the engineer still feels like a babe-in-the-woods, afraid to apply what he has learned to a field he is not quite sure is definable and governed by laws and rules.

The professional economists are much bolder. American economic history has had quite a peculiar brand of "scientific economic thought" applied to it. Every up and down trend of its economic life has been carefully indexed and studied. In the wake of every depression analysts knew exactly what would have prevented it. This remedy was diligently recorded and confidently saved to be applied for the next rainy day. But each time something went wrong; the remedy would have been all right, had the conditions not changed. But history does not stand still. The economy is in a constant state of change. And so what would have saved the depression of 1903 proved totally ineffective in 1920. What would have saved the country in 1920 proved disastrous in 1929. Now we know what should have been done in 1929 and we are ready to use it in 1958.

Is a scientific approach to economics possible? Aren't we dealing in an area where variables are too many to forestall any intelligent prediction, let alone steps to correct its misbehavior? In the final analysis the answer may well be NO. For in spite of the popular saying, history does not repeat itself but moves constantly forward. This constant change may be the only key to an ever booming economy.

There is nothing new in analog solutions and they are used in technical problems every day. Just as it is easier for the electrical engineer to solve a mechanical problem by setting up an electrical analog, it should be easier for us to comprehend and solve an economic problem by converting it into a techincal analog. For instance, consider the following economic phenomena: our labor and industrial facilities—the input; our production—the output; subsidies in every form—feedback; regulatory agencies and planning—controls; and so on down the line. The problem we are contending with now is on much more familiar ground. And yet the conclusion which one must draw is not necessarily an easy one. Mostly because of our highly developed individualism, we hold the idea sacred even when applied to the community as a whole, which by definition alone is the opposite of individualism. So if we drop this psychological block for one moment and go back to our analog, it is quite obvious that the key ideas become controls and the extent to which we are ready to apply them. In economic terms, controls translate into planning and regulation. Realizing this, it is here that engineering management can make its greatest contribution.

Why can't we attempt to organize all possible input variables, feedback information into an engineered system that can accurately predict and then control—within the bounds of accepted economic freedoms—the status of our economy such that we can minimize wrenching ups and downs. Certainly, it is a fantastic job, but no more fantastic that putting an artificial satellite into orbit twenty-five years ago.

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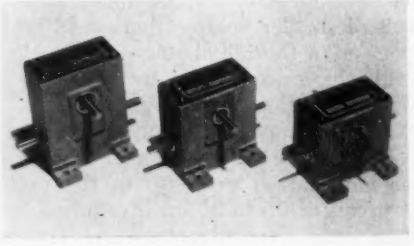

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